MOSQUITO SURVEYS

A HANDBOOK FOR
ANTI-MALARIAL AND
ANTI-MOSQUITO
FIELD WORKERS

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A HANDBOOK FOR ANTI-MALARIAL AND ANTI-MOSQUITO FIELD WORKERS

BY

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FOREWORD

BY

SIR RONALD ROSS, K.C.B., K.C.M.G., F.R.S.

MR. MALCOLM E. MACGREGOR, M.A. (CAMB.), has done me the honour to ask me for a foreword to this complete and important book. During the War, Captain MacGregor, R.A.M.C. (T. F.), was first employed under me at the War Office to deal with the prevention of malaria in England, where we (rightly) expected an outbreak of the disease in consequence of many cases of malaria being sent home from Salonika and East Africa. He was then ordered abroad to East Africa, in charge of the British Mobile Laboratories, and finally, at the end of the War, was stationed at Sandwich in charge of the War Office Entomological Station there, and also in charge of the anti-malaria measures which had been necessitated by the anticipated occurrence of cases in that district. In 1922 he was sent to Mauritius on behalf of the Colonial Office, in order to make a thorough study of malaria there, in continuation of the rather brief investigations which Major Fowler, R.A.M.C., and I had commenced in the years 1907 and 1908. Since then, as stated on the title page, he has

been employed by the Wellcome Bureau of Scientific Research at Wisley in investigating those insects which convey disease.

The author of this book is, therefore, a very accomplished expert in the subject of which he treats; and the book itself is perhaps a fuller exposition of that subject than has yet appeared, and will be indispensable to all workers connected with the prevention of tropical diseases. With all the knowledge which we now possess about malaria and anti-mosquito measures, one of our main needs for more rapid progress is a still closer scientific contact with the problems which remain unsolved. The reality of these problems and the economic gain to the Empire which their solution will spell are not yet sufficiently realised, although more than a quarter of a century has passed since the time when malaria was shown to be carried by the insects with which this book deals.

At the same time, the author has been obliged to limit the area covered by his work. He cannot possibly exhaust the large subject of actual mosquito-control, because this phylum would require another work of similar or greater magnitude. His exact aims are set forth both in the introduction and in the conclusion, and are of themselves sufficient to encourage all

workers on the subject to pay close attention to his pages.

The public in this country and, I fear, in many of our tropical possessions, has little conception of what malaria means to the Empire. It means the paralysis of industry in many of the more fertile tracts; it means the wastage of money in connection with the sickness of vast numbers of people; it means the loss of productive power on numbers of estates and in thousands of towns and villages; and, finally, it means the loss of something like one or two million lives every year, and the loss of health in many more millions of people. We are apt to stand aghast when we remember the huge mortality caused by the recent War, but pay little or no attention when a similar mortality is caused by a disease—not only during a few years, but for all time, past and present and until the future shall show sufficient intelligence and vigour to deal with the plague with which Mr. MacGregor is concerned.

RONALD ROSS.

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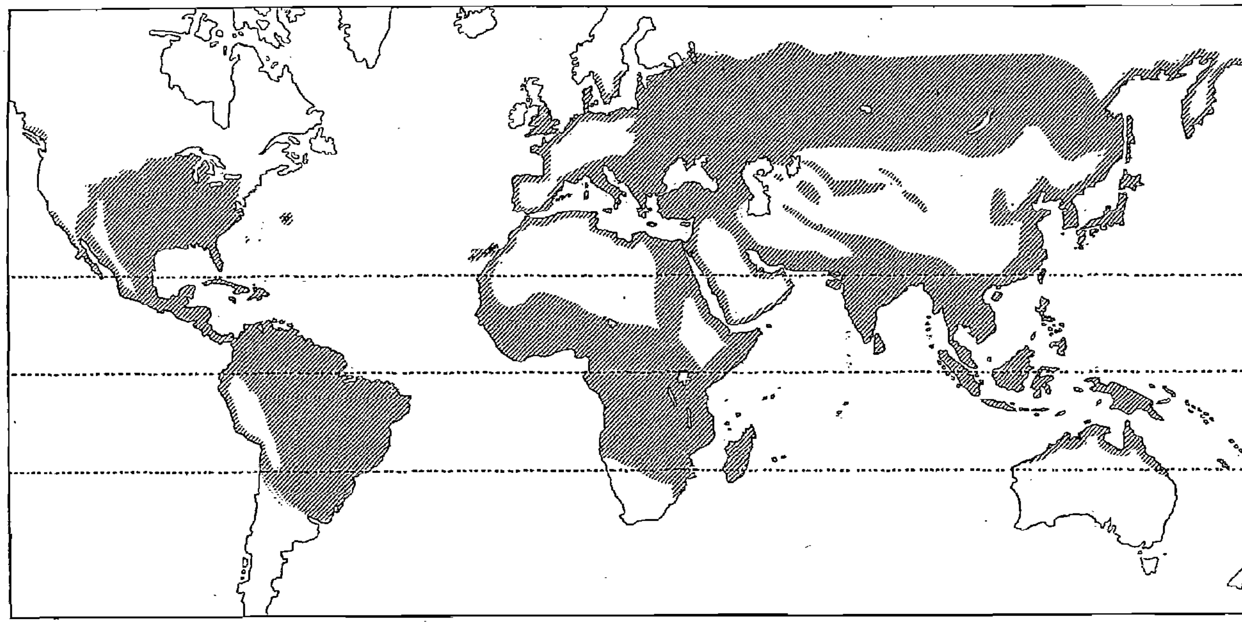

Map Showing Distribution of Malaria

(After James and Christophers "The Practice of Medicine in the Tropics"--Byam and Archibald)

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INTRODUCTION

DURING my visit to Mauritius, in 1922-1923, it became apparent that a small handbook dealing with the mosquitoes of Mauritius and Rodriguez was greatly needed to provide information to the officers and members of the Medical and Health Department in regard to the species of mosquito which are at present known to inhabit these two Islands. This little book will, I hope, be found to fulfil this function and will, at the same time, provide a brief explanation of the anatomy and bionomics of mosquitoes to persons associated with the anti-mosquito measures who have not hitherto had an opportunity of acquiring an entomological knowledge. Possibly it may go further and, to some, serve as an introduction to the study of mosquitoes in general, for most of the many and excellent handbooks that are already available surmise considerable previous entomological training on the part of the student. Therefore, until the student has become conversant with Part I of this little book, I have assumed that the whole subject is new to him. Considerable experience in many parts of the world has, moreover, demonstrated that Mauritius, nevertheless, is but one instance where the need of such a guide to the field worker is manifest.

It is clearly impossible, however, to produce a small handbook which will deal with all the mosquito species of all parts of the earth, and, for this reason, I am utilising to some extent the hitherto incompletely described mosquito fauna of Mauritius and Rodriguez as a theme by which to interpret the essential information to field workers in many lands. Since the mosquitoes of most territories nowadays have been studied, either completely or at least partially, by competent systematists, there are usually valuable records available of the species found to occur in any particular region. Consequently, if medical officers of health, field workers and other persons engaged in anti-malaria and anti-mosquito campaigns can be provided with a knowledge of the general life-histories, bionomics, and the Tribal, Generic and Sub-generic divisions of the Culicidæ, they may be fairly safely left in a position from which they may for themselves recognise the species of their own territory with the aid of the existing records and related identification keys.

Entomology, from the aspect of Public Health, is still inauspiciously regarded as the Cinderella of the related sciences, yet in reality Entomology is no less important than her sisters, and in the Tropics she is ultimately likely to be found worthy of proper attire, and to repay abundantly all that is spent on her. The present attitude towards Entomology is perhaps to be explained from two separate aspects. First of all, admittedly, the days are over when sensational interest in Entomology, born of the discoveries that insects

carry disease, is focused upon it. We know most of the insect-vectors nowadays, and it seems unlikely in future that more than possibly one or two other human diseases will be proved to have an insect-transmitter. What is known is frequently no longer feared, and then often may even fail to sustain interest. That is the first and possibly the less important explanation. In the second, we have the fact that Entomology is a science in itself, a special training is necessary, and, in the turmoil of the multifarious studies of the embryo sanitarian it has hitherto been thought that if anything of the training is to be sacrificed the training in Entomology could best be chosen. Thus, in the end, the qualified sanitarian departs to his place in the tropical sun with frequently only the mere rudiments of a knowledge of Entomology at his command. Almost immediately he realises, under the circumstances, that of Entomology he has been taught to recognise laboratory specimens, and little else, and, faced with conditions in the field, he finds he has no reliable compass by which to steer. Prudence asserts itself, and the average sanitarian in such a plight shies, and deals with other matters. Ere long his attention is fixed elsewhere, and an interest once lost in a subject is apt inadvertently to stigmatise the subject as unimportant. Consequently, Entomology to some extent shares the fate of Cinderella meanwhile.

But though the days of the sensational insect-vector discoveries are past, there still remains the work of acquiring and applying the accumulated entomological knowledge, which, when sufficient

men are devoting themselves to the subject, will mean the final release of vast areas of the earth from the control of the insect-vectors and the present human misery they inflict.

In dealing with mosquitoes, it is nowadays essential to abandon the happy-go-lucky methods of the past, when, in connection with anti-mosquito measures in the field, it was thought sufficiently exact to differentiate between mosquitoes by saying that a certain specimen was either "an Anopheles or a Culex"—though in reality it was quite possibly neither!—and all who are ever to make headway against the mosquito pest by instigating and bringing to a successful issue properly-designed anti-mosquito campaigns must first of all obtain a clear understanding of the constitution and bionomics of the mosquito community. Study on the right lines will show that to acquire this essential knowledge is both easy and interesting, and it will be realised at once that happily mosquito species, from the aspect of public health, are to be classed either as important or unimportant species; and that, fortunately, moreover, it is only the minority which are of importance. Ambitious schemes for campaigns designed to annihilate all the mosquitoes in a given locality are generally the conception of inexperienced enthusiasm, and will speedily bring the designer face to face with the futility of his aim and the bankruptcy of his resources. By a complete study of the local mosquitoes, the best that we can do in most cases is to determine which are the dangerous species, and confine our campaign to these. Concentrated against the important

species, our efforts are thus not needlessly dissipated, and more economically may be calculated so to weaken the enemy that the balance of the combat is always in our favour. Because we happen to know that most anopheline mosquitoes breed in rural swamps, ponds and rivers, it is far from sufficient to plan the details of the campaign so as to deal indiscriminately with the waters of such places. Only by the careful study of the bionomics of each particular species can economical and thoroughly efficient measures be designed to furnish a satisfactory means of control. It will often be found that anti-measures for one species are inapplicable to another, and vice versa, as the case may be.

Within this book I have touched on the possible origins of the mosquitoes which now occur in Mauritius and Rodriguez. The two Islands are not at all alike in their mosquito communities, and the most satisfactory theory would seem to be that each Island has attained its mosquito population by independent accidental importations.

All who deal with the mosquitoes of Mauritius and Rodriguez and the neighbouring islands should therefore realise that the list of species may at any time be increased by further accidents of the same kind, and the serious worker should not confine himself to a study merely of the genera represented there at present. It is for this reason, and also for the service of workers in all parts of the world, that I have included Mr. F. W. Edwards'

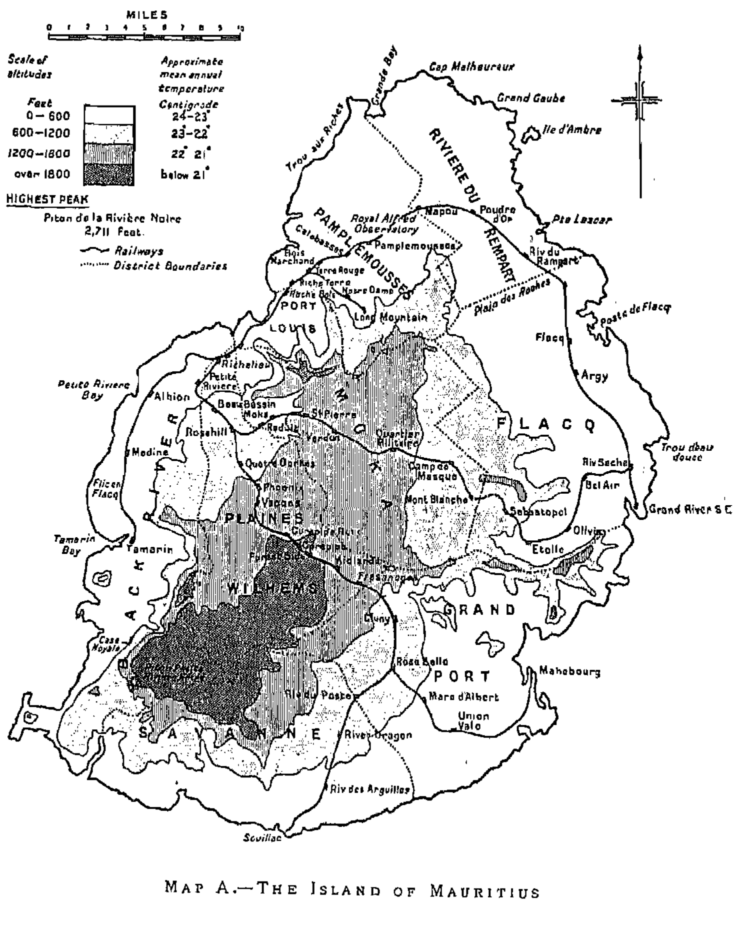
latest complete generic classification of both the *Anophelini* and *Culicini* (*pages* 98 *and* 99 *and* 184-188). If, at any time, a species of what is thought to be a new genus is found, it can, by the use of these keys, be referred to the correct genus, and the specific identification may be made subsequently, either by the use of the keys associated with the previous local records, or by sending the specimens to one of the recognised systematic authorities.

The mosquitoes of Mauritius have been studied previously by several people, noteworthy among whom are Mr. d'Emmerez de Charmoy, C.B.E., Mr. Daruty de Grandpré, Sir Ronald Ross, K.C.B., K.C.M.G., F.R.S., and Col. C. E. P. Fowler, O.B.E. These gentlemen have, in fact, the credit of the collection and description of many of the earlier known species, and Mr. d'Emmerez de Charmoy for years made the study of the local species one of his principal works, although, since Ross' and Fowler's survey, he has had to devote his attention to entomological problems concerning agriculture.

The section of this book which deals with the particular species of mosquito found in Mauritius and Rodriguez, if not always directly serviceable to workers elsewhere, will, I hope, at least indicate what constitutes the important bionomical records, and thus serve as a guide to the formation of valuable records on other species.

In this little treatise, I regret to say, the study and description of the eggs of the different local species is hardly more than mentioned. The

investigations on the biology and bionomics of the four Mauritian anopheles, which was the principal object of my visit to Mauritius, left me with only limited time to devote to other matters, and I had therefore reluctantly to forego a careful study of the egg-stages. From what I saw of the subject, however, there is no doubt that the specific differences in the structure of the eggs would prove a valuable and interesting subject for research, and I commend it to the attention of future workers in those Islands.



MAP A.—THE ISLAND OF MAURITIUS

THE MOSQUITOES OF MAURITIUS AND RODRIGUEZ

THE Island of Mauritius lies in the South Indian Ocean 470 miles east of Madagascar ; and 365 miles east and a little to the north of Mauritius lies the small sister Island of Rodriguez. About 80 miles to the west of Mauritius is Réunion (Bourbon), and these three Islands, together with a few associated islets, compose what is known as the Mascarene Island Group.

Mauritius, although only a small island having a superficial area nearly the same as that of the County of Surrey in England, nevertheless, has a remarkable range of climatic conditions in its separate districts. Along the sea coast in the different areas the climate is either hot and steamy, or hot and dry. Further inland, on the west and northern sides of the Island, the climate is hot and comparatively dry, whereas on the southern and eastern sides the climate is humid. At the central and elevated districts of Mauritius, the climate is not unlike the spring, hot summer and early autumn months in England. Rain falls in the central districts all the year round, but a distinct dry and wet season is maintained along the lower levels of the Island. Large forests occur on the highlands, and the Island, as a whole, is well wooded. The numerous rivers and streams which drain Mauritius on all sides have a radial course with their sources usually situated high up among the hills. The river-beds are mainly of basaltic rock, along which large boulders are strewn in

profusion, causing cascades and small rapids. The broken flow of the water at all times, and the headlong rush of the tropical torrents during the wet season, cut out numerous holes in the rocky beds of the rivers and thus form sheltered breeding-places for many of the Mauritian mosquito species. As the rivers reach the coast at sea-level, they often widen out and form extensive marshes—the most extensive of all mosquito breeding-places in the Island. (*Map* A, *page* 20.)

Streams, rivers, marshes, ponds, lakes and holes in the ground, in rocks and in trees, are the naturally formed breeding-places of the mosquitoes, while the breeding-places provided by human agency are, in the order of their importance, the water-logged sugar-cane plantations (when excess of water has been permitted), faulty drainage canals and irrigation systems in towns and in rural districts, faulty wells, water-tanks and water-barrels (unprotected from mosquitoes, their eggs being laid on the water in these containers), faulty rain-gutters, flower and fountain-basins (unless they are stocked with small fish and kept free from algal and weed growth), old tins, broken bottles and other receptacles that will collect and hold water sufficiently long to enable the immature stages of the mosquito to develop.

With its hot climate during the summer months, and with a temperature all over the Island during the winter that is never sufficiently low, even at the highest altitudes, completely to check the development of the hardier species; with its abundance of natural and artificial breeding-places, its warm climate at all times of the year along the coastal belt,

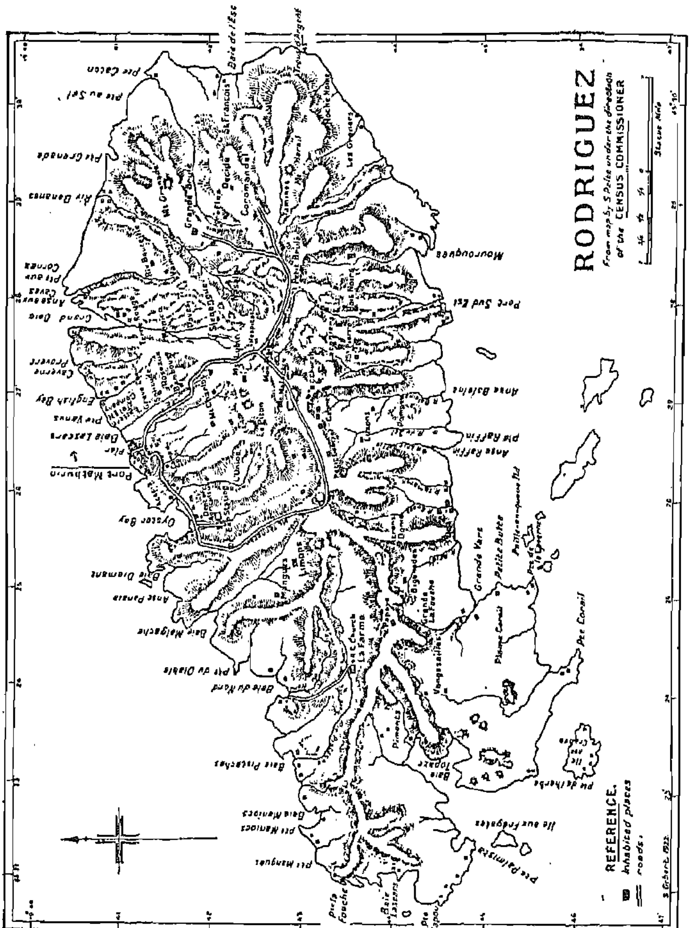
and with its dense human population, Mauritius, it will be easily realised, offers a very favourable habitat to mosquitoes.

Up to the present time, 18 species of mosquito, representing five separate genera, have been collected in the Island.

Rodriguez is an isolated little island about nine miles long and four miles across its greatest width. In some respects it is very similar to Mauritius, since it is well wooded, especially at the elevated regions, well provided with naturally formed breeding-places, and has a dense human population totalling nearly 7000 persons. Unlike Mauritius, however, it has only three species of mosquito at present, none of which are anophelines. Endemic malaria in Rodriguez is therefore unknown, whereas in Mauritius it is a veritable plague, since three of the anopheline mosquitoes found there are notorious vectors of the disease. (*Map* B, *page* 24).

Possible Origins of the Mosquitoes in the Two Islands

Mauritius and Rodriguez form part of what is known as the Mascarene Island Group. The two Islands belong to Britain, but the third important member of the Group, Réunion (Bourbon), belongs to France. Very little is known about the mosquito fauna of Réunion, but, as it lies only 80 miles to the west of Mauritius, it is probable that most of the Mauritian mosquitoes are common also to Réunion. However, as one species of mosquito has been found in Rodriguez that does not occur in Mauritius, and many in Mauritius



MAP B.—THE ISLAND OF RODRIGUEZ

that do not occur in Rodriguez, it is quite likely Réunion may have species which are not found in the two other islands.

We can only speculate on the origin of the mosquitoes which inhabit these islands. Two theories have been advanced. The first assumes that all the islands of the Mascarene Group are but the remnants of one large continent which extended northwards. This assumption would mean that the majority of the mosquitoes of all the islands belonged to the now vanished continent, and, in order to explain the differences in the mosquito fauna of the islands, we should have to adopt the theory of strict regional distribution, and maintain that Rodriguez, even at the time of continental inclusion, never had anopheles present in that region. Similarly, the fact that another mosquito (*Culex simpsoni*) which occurs on Rodriguez and not on Mauritius would have to be explained in a like manner.

On the other hand, if we assume that the Mascarene Group has been formed mainly by volcanic eruption (of which there is considerable evidence), then all the mosquitoes now inhabiting these islands, in the course of time have been accidentally imported, either in the form of eggs, larvæ, pupæ, or adults. Many of the species of mosquitoes that are found in the islands of this Group are common either to Africa or India, and if it be true, as many people maintain, that *Anopheles costalis* did not occur on Mauritius much before 1865, then here within living memory is an example of the accidental introduction of an exotic species ; and it is quite probable that the other species of mosquito have entered Mauritius and Rodriguez from different parts of the world just as accidentally. Moreover, the fact that

Rodriguez is still free from anophelines would seem that the accident of its importation to the Island has not yet taken place—and it is to be hoped that human intervention may prevent its introduction, with the trail of misery that would inevitably follow the consequent spread of malaria among the inhabitants.

In spite of all conjectures, however, the actual origin of these islands will probably never be known, and it is safer, I think, to account for the mosquitoes by the immigration theory, bearing in mind the lesson it has furnished and the need for careful mosquito-control measures, lest additional pests are introduced.

PART I

THE PRIMARY CLASSIFICATION, ANATOMY AND BIONOMICS OF MOSQUITOES

THE PRIMARY CLASSIFICATION OF MOSQUITOES

Fundamental information

Now the first important matter for those engaged in anti-mosquito measures is the requisite information to be able to answer definitely the question—"Is this a mosquito, or is it some other small insect like a mosquito?" In the course of my investigations in different parts of the world, I have often been presented by medical officers and others with a variety of insects and this same question. There should be no difficulty in telling whether a certain insect is a mosquito or not.

Mosquitoes are small two-winged flies, and are therefore included in the Zoological Order, *Diptera* (Gr. δίπτερος = with two wings). In this Order there are many Sub-Orders. One of the Sub-Orders is called the *Nematocera* (Gr. νῆμα = thread; κέρας = horn = antenna). Flies belonging to the Sub-Order *Nematocera* have the following characters; they are all small midge-like flies; the body is subdivided into three clearly differentiated parts; the head, thorax and abdomen, the latter being cylindrical, elongate and composed of conspicuous segments. The head carries two thread-like antennæ consisting of numerous similar or nearly similar segments, which are often ornamented with fine projecting hairs. The number of the segments of each antenna is at least six, and often as many as 14 to 16. The legs are long and slender.

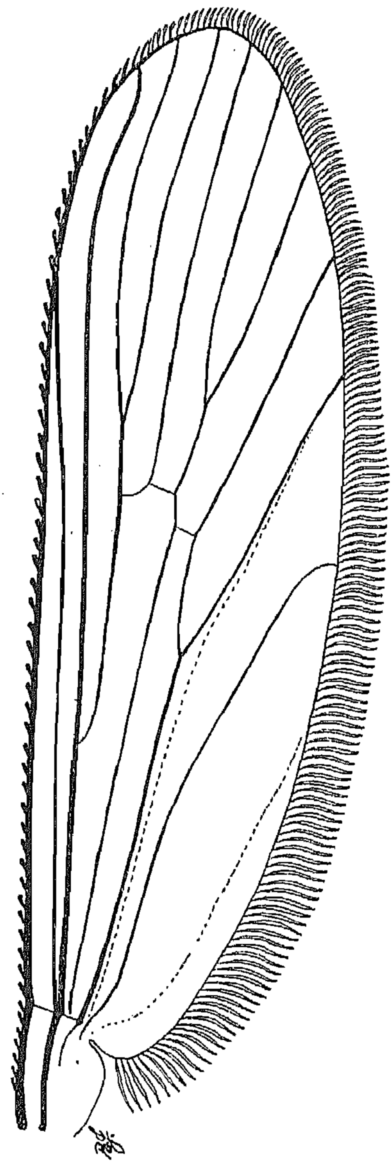


FIG. 1.—TYPICAL VENATION OF A MOSQUITO'S WING

So far, then, the insect in question must first of all conform to these characters if it is even faintly to resemble a mosquito.

To carry the analysis further, we have next to refer the insect to the characters of one of the many separate Families of the *Nematocera*, i.e., the *Culicidæ*.

The *Culicidæ* are small slender flies, with a long or short proboscis, *but* (with the exception of the unimportant Sub-Family *Dixinæ*) *having along the posterior margin of their delicate membraneous wings a dense fringe of backwardly projecting scales (often hair-like), while the wings have the complete (often scale-clad) venation shown in Fig.* 1, *page* 28.

Small flies which do not conform to this description do not belong to the Family *Culicidæ*, and therefore are not mosquitoes.

The Family *Culicidæ* is divided into three Sub-Families: (1) the *Dixinæ*, (2) the *Chaoborinæ*, and (3) the *Culicinæ* (the Mosquitoes).

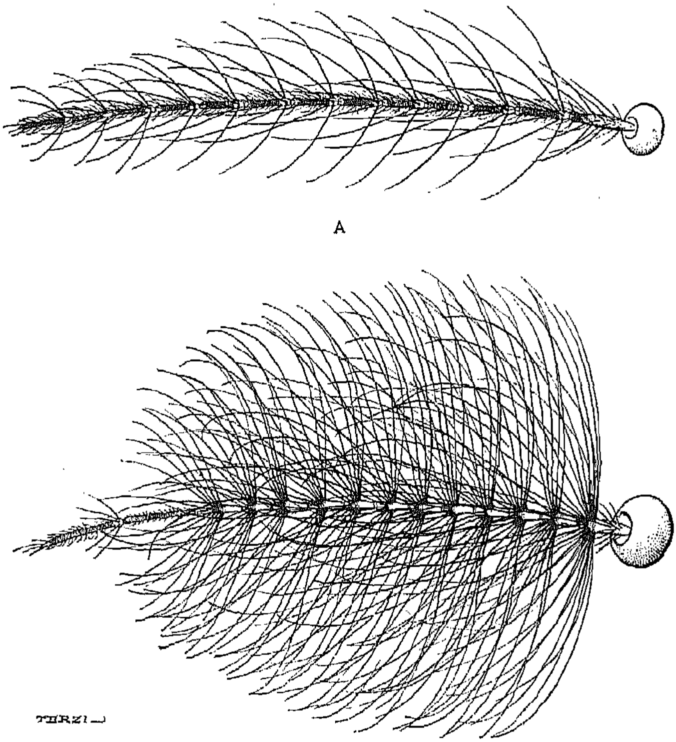
The first two of these Sub-Families include small mosquito-like insects, which, however, are not armed with long proboscides. They are consequently not blood-sucking insects, and are of no importance from the standpoint of public health.

The third Sub-Family, the *Culicinæ*, are similar small insects, *but all are armed with a long proboscis whose length approximately equals the combined length of the head and thorax.*

Whether an insect is a mosquito or not can be settled, therefore, by seeing if it conforms to all these essential structural features. We may summarise the matter by saying that an insect, to be a mosquito:—

(1) must belong to the Sub-Order *Nematocera*, i.e., have thread-like antennæ composed of from 6 to 16 short, similar, or nearly similar joints, and have long slender legs;

(2) it must belong to the Family *Culicidæ*, i.e., have membraneous wings which carry a fringe of backwardly directed scales along the posterior

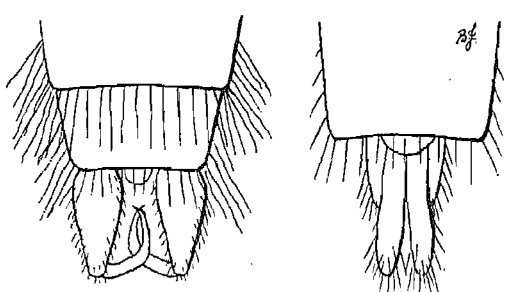


A

B

FIG. 2.—MOSQUITO ANTENNÆ

A—female antenna ; B—male antenna (After W. D. Lang. "A Handbook of British Mosquitoes")



A B

FIG. 3.—TERMINAL END OF MOSQUITO ABDOMEN

A—male ; B—female

border, and have the type of wing venation shown in *Fig.* 1, *page* 28 ; and, finally,

(3) it must belong to the Sub-Family *Culicinæ*, by having a long proboscis whose length is approximately equal to the combined length of the head and thorax.

The relationship of these different divisions of the *Diptera* is graphically illustrated as follows :—

Phylum, *Insecta*.

Order, *Diptera*.

Sub-Order, *Nematocera*.

Family, *Culicidæ*.

Sub-Families—

1. *Dixinæ*. 2. *Chaoborinæ*. 3. *Culicinæ*.

With the question, "Is this a mosquito ?" definitely settled, we have to deal with another important question from the standpoint of the investigator, *i.e.*—"Is this mosquito a male or a female ?" Among the vast majority of mosquitoes the answer to this question can readily be determined by an examination of the insect's antennæ. Male mosquitoes, as a rule, have their antennæ heavily studded with long hairs which give the antennæ a conspicuously plumed appearance. Female mosquitoes, on the other hand, as a rule, have their antennæ sparsely ornamented with long hairs, and the general appearance of the antennæ is thread-like (*Fig.* 2, *page* 30). Since there are, however, a few species of mosquito (none of which, so far, have been found in Mauritius or Rodriguez) which have thread-like antennæ in both sexes, should there be any doubt in the mind of the observer as to whether the insect is a male or female mosquito, the structure of the external genitalia at the tip of the abdomen should be examined

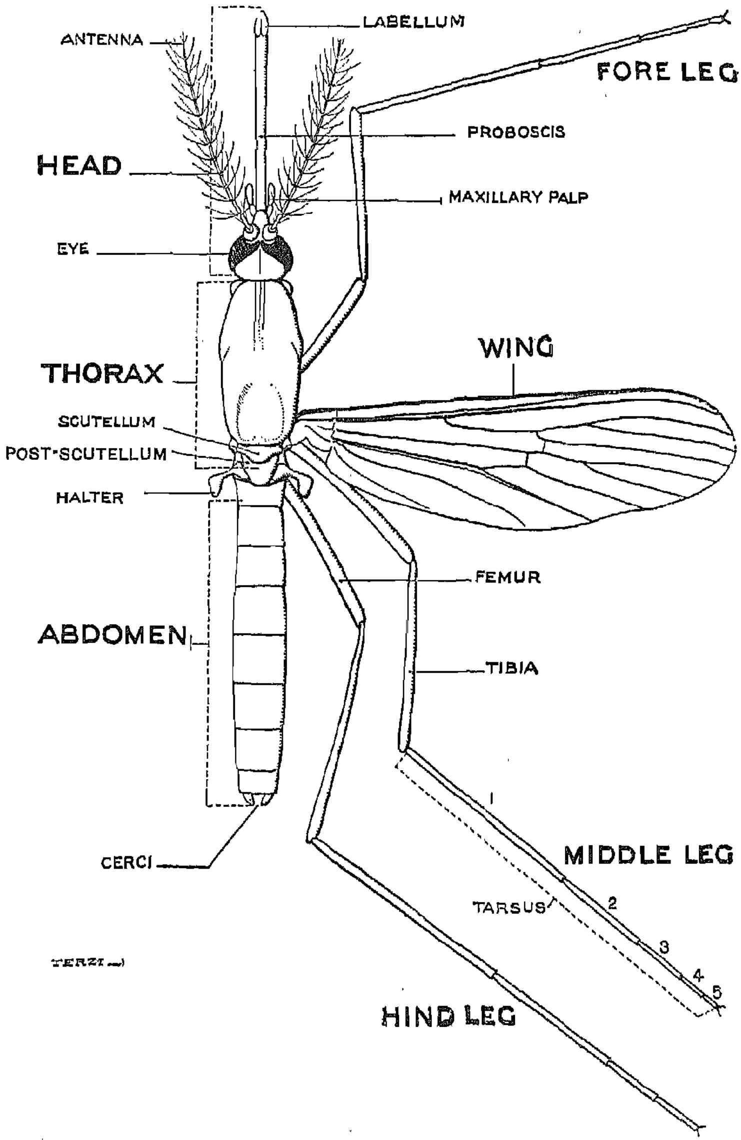


FIG. 4.—GENERAL MORPHOLOGY OF A MOSQUITO (Female)
(After W. D. Lang. "A Handbook of British Mosquitoes") *(Modified)*

under a strong hand-lens or under the microscope. The external genitalia of male mosquitoes *(hypopygium)* have two hook-like appendages called the claspers which form a conspicuous male character. The tip of the abdomen of male mosquitoes, on account of the broad structure of the hypopygium, is somewhat broadly terminated (*Fig.* 3, *page* 30). In female mosquitoes the external genitalia are not conspicuous, except for two small papillæ *(cerci)* which project, either longitudinally or vertically, from the terminally more pointed abdomen (*Fig.* 3, *page* 30).

Morphological Characters of Mosquitoes

Like other insects, the bodies of mosquitoes acquire their rigidity by an external coat *(exo-skeleton)* of a hard horny substance called *chitin* (Gr. χιτών = a coat of mail). Chitin is a substance excreted by the cells of the true skin *(cuticle)* of the insect which envelopes the insect's body. Joints, or articulations, are formed in the chitinous "coat of mail" where necessary (as, for instance, to form the joints of the head, legs, abdomen, etc.), by the non-excretion of chitin by the cuticle at these situations. At the joints, therefore, the unchitinised, or only very lightly chitinised, cuticle may be observed. The chitinised parts of mosquitoes bear numerous hairs and scales of extremely varied form and colour. In some species the scales have a brilliant metallic sheen, and it is these hairs and scales which produce the striking ornamentation of many species.

Fig. 4, *page* 32, shows the general morphology of a mosquito.

In describing insects, the words "basal" and "apical" are constantly used. We have, therefore, to settle the significance of these two words when they are employed in relation to the "basal" and "apical" portions of the joints, segments,

etc. The significance is simply demonstrated if a real or imaginary pin be passed through the middle point in the body of an insect.

The basal region of any particular segment, joint, etc., is then that point which lies nearer the pin, while the apical region of the same segment, joint, etc., is that part which lies further from the pin. It is thus important to realise that the apical portion of, say, one of the joints of the antennæ has an exactly opposite orientation to the apical portion of one of the abdominal segments, for instance. However, no confusion can arise if it be kept in mind that the centrally-placed pin through the body of the insect represents the theoretical *basal point* from which the "basal" and "apical" portions of the other parts of the body are estimated.

The Head is sub-globular in form and most of its anterior and lateral surfaces are occupied by the two large compound eyes whose numerous separate facets can be seen under a microscope or with the aid of a strong hand-lens. In the median line of the head, below the eyes, is a protuberance called the *clypeus*, from which extends the long cylindrical *proboscis*, flanked, one on each side, by two other rod-like organs termed the *maxillary palpi*. These two palpi are usually composed of four joints. In the female sex of many genera the palpi are quite short, less than a quarter of the length of the proboscis, but in other genera they may be half or fully as long as the proboscis. In the male sex of nearly all the genera the palpi are either as long as or longer than the proboscis. This is true of all the known species of Mauritius and Rodriguez, but it is as well to note the fact that in some of the *Aëdes*, *Deinocerites*, etc., species found in other parts of the world, the males and females both have short palpi. The maxillary palpi of mosquitoes are clothed with hairs and scales, and are sometimes strikingly ornamented by

patches of coloured scales, and in the males by plumes of long hairs.

The proboscis (*Fig.* 5, *page* 36), as it extends from the head when the mosquito is at rest or dead, forming then as it does an apparently single rod-like organ, actually consists of a tubular sheath called the *labium* which terminates at its apex in two small pads termed the *labellæ*. The labium ensheaths the piercing apparatus of the proboscis, and is divided by an opening running its entire length along the upper or dorsal surface. Ensheathed within the labium are six long, slender piercing organs. These are (1) a pair of *maxillæ*, (2) a pair of *mandibles*—the organs that are actually used for cutting through the skin of the animal or plant host—and (3) the *labrum-epipharynx* and *hypopharynx*, which, by their apposition, form a minute tube to convey the blood or plant sap through the œsophageal pump and œsophagus to the insect's stomach. Within the hypopharynx there is a minute central canal extending from base to tip, down which the saliva from the salivary glands of the mosquito is injected into the victim. The saliva has two functions. By containing an anti-coagulin, it prevents the coagulation of the blood within the tube formed by the apposition of the labrum-epipharynx and the hypopharynx, and also by containing irritant substances it sets up an hyperæmia in the tissues surrounding the site of entry of the proboscis, thus causing a larger supply of blood to be available.

The Antennæ (*Fig.* 2, *page* 30). These are two thread-like appendages, composed of 15 separate joints, situated on the antero-dorsal surface of the head. The basal joints of the antennæ are generally spherical in form; and from their depressed centres the second and short rod-like segments of the antennæ spring, followed usually by other very similar rod-like segments.

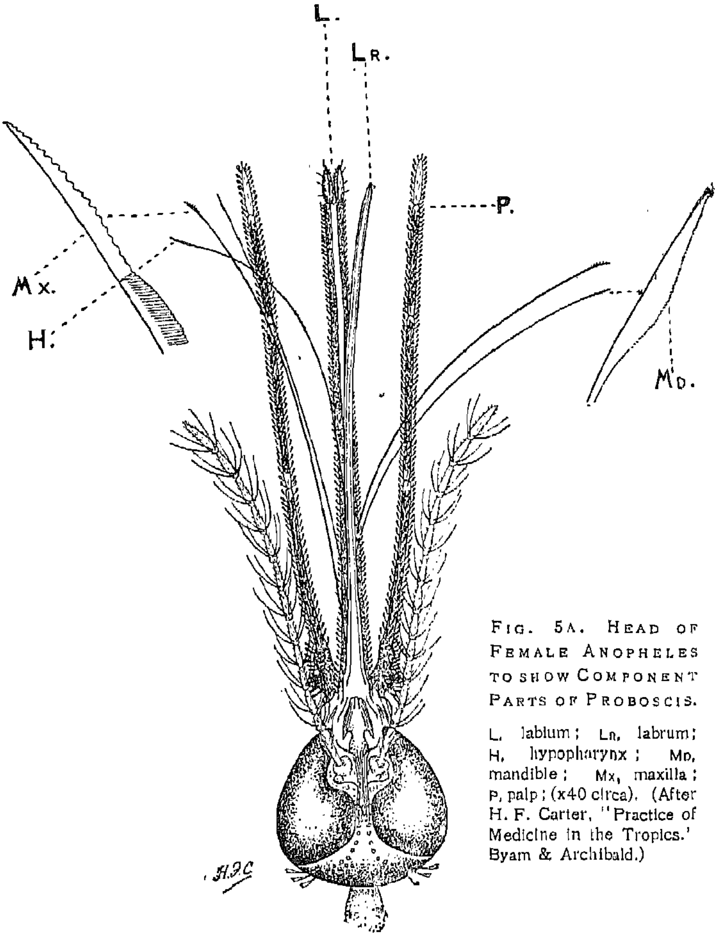
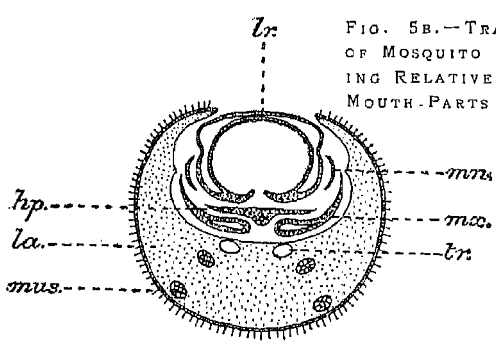


FIG. 5A. HEAD OF FEMALE ANOPHELES TO SHOW COMPONENT PARTS OF PROBOSCIS.

L, labium; LR, labrum; H, hypopharynx; MD, mandible; Mx, maxilla; P, palp; (x40 circa). (After H. F. Carter, "Practice of Medicine in the Tropics.' Byam & Archibald.)

FIG. 5B.—TRANSVERSE SECTION OF MOSQUITO PROBOSCIS, SHOWING RELATIVE POSITIONS OF THE MOUTH-PARTS WHEN AT REST.

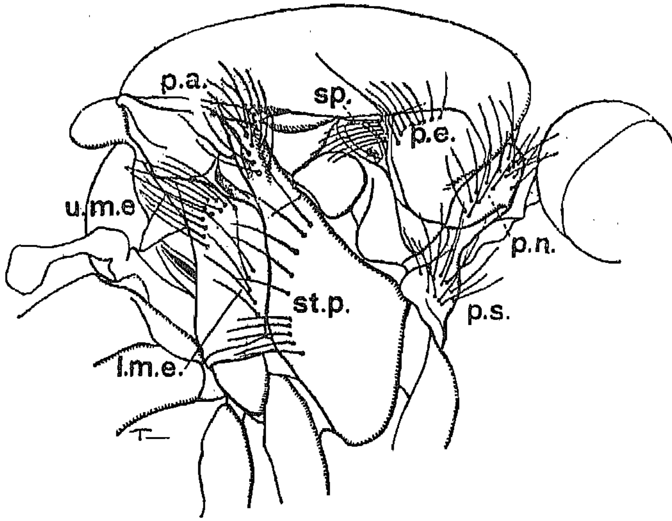


la., labium; *lr.*, labrum; *mn.*, mandible; *mx.*, maxilla: *hp.*, hypopharynx; *tr.*, tracheæ; *mus.*, muscle. (After Nuttall & Shipley, Journl. of Hyg., Vol. 1.)

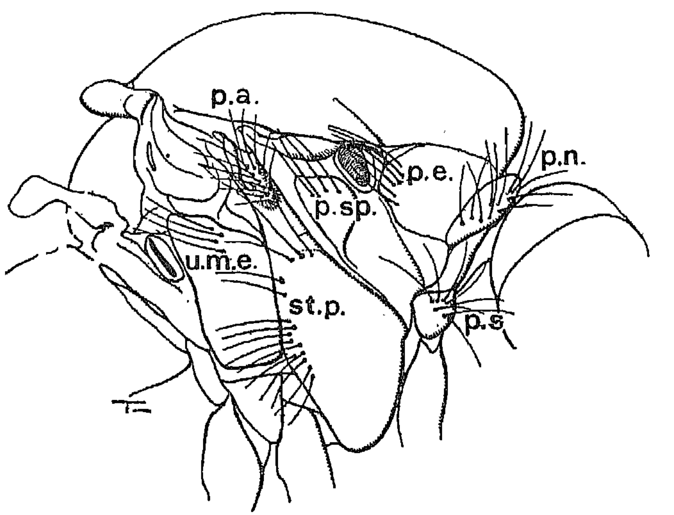
The terminal joints are anteriorly rounded, and in some species thickened. At the articulations there are long hairs which may be few in number or so numerous as to give the antennæ a plumed appearance. In this respect the sexes of most species of mosquitoes differ strikingly : the antennæ of the males being densely clothed with long hairs, while those of the females are sparsely hair-clad so that to the unaided eye the antennæ of the females are simple thread-like organs quite unlike the conspicuous plumed antennæ of the males. As previously mentioned, it should be borne in mind that while there is this characteristic difference in the structure of the antennæ of the two sexes in most of the genera and species of mosquitoes, there are a few in which there is no difference in the form of the antennæ between the males and the females, the type of the antennæ in these cases being in both sexes thread-like with a few scattered hairs along their course.

Around the basal joints of the antennæ ornamental coloured scales frequently occur in many species, and these, with the other scale markings on the body, are of taxonomic importance. Between the inner aspects of the basal joints of the antennæ is a space extending down between the eyes to the clypeus. This space is termed the *frons*, and it, too, in some species, is ornamented with scales and long hairs. Over most of the top (dorsal aspect) of the head the two compound eyes are contiguous, but separate towards the back of the head, leaving an area which is termed the *occiput*, or, more popularly, the *nape*. This area is nearly always richly clothed with scales of many forms and long hairs, whose structure differs markedly among the species.

The head of a mosquito is attached to the thorax by an unchitinised short flexible neck, but as the back of the head of a resting mosquito is nearly in



A



B

FIG. 6

Side view of thorax of (A), *Theobaldia annulata*, and (B), *Aëdes geniculatus*, to show arrangement of sclerites and pleural bristles (scales omitted). Bristles: p.n. pronotal; p.s., prosternal; p.e., proepimeral; s.p., spiracular; p.sp., post-spiracular; p.a., pre-alar; u.m.e., upper mesepimeral; l.m.e., lower mesepimeral; st.p., sternopleural. (After F. W. Edwards)

contact with the adjoining aspect of the thorax the neck is protected from injury by the overhung front part of the thorax, and it can, therefore, not be easily seen unless the head of the insect is forcibly extended by means of a pair of dissecting needles.

The Thorax. The thorax of the mosquito lies between the head and the cylindrical segmented abdomen, from which it is easily distinguished. The thorax itself is also segmented, but the constituent segments are fused to form a rigid whole, and the segmentation is not clearly visible. It is anatomically divided into three portions, which are known respectively as the *pro-thorax*, *meso-thorax* and *meta-thorax*. Each main division of the thorax is composed of chitinised plates, *sclerites*, with lines of division, *sutures*, between them. The dorsal plates are collectively termed the *tergites*, and respectively are known as the *pronotum*, *mesonotum* and *metanotum*. In mosquitoes, the pro-thorax and meta-thorax are much reduced in size, the thorax consisting therefore mainly of the middle portion or meso-thorax.

From the dorsal aspect, the pro-thorax is so much reduced that it is visible only as small lobe-like structures situated one on each side of the anterolateral aspects of the meso-thorax. These lobe-like structures are termed the *pro-thoracic lobes* or *patagia*. The mesonotum (*i.e.*, the tergite of the meso-thorax) is made up of three portions: (1) the principal dorsal portion of the thorax, termed the *scutum*, (2) a small backwardly projecting ridge, the *scutellum*, which partially overhangs (3), the dome-shaped posterior portion, termed the *post-scutellum*.

The meta-thorax is so far reduced in size as to be represented merely by a narrow band of chitin, the *metanotum* between the post-scutellum and the first abdominal segment.

The lateral aspects of the thorax are termed the *pleuræ*. In the simplest examples of insect

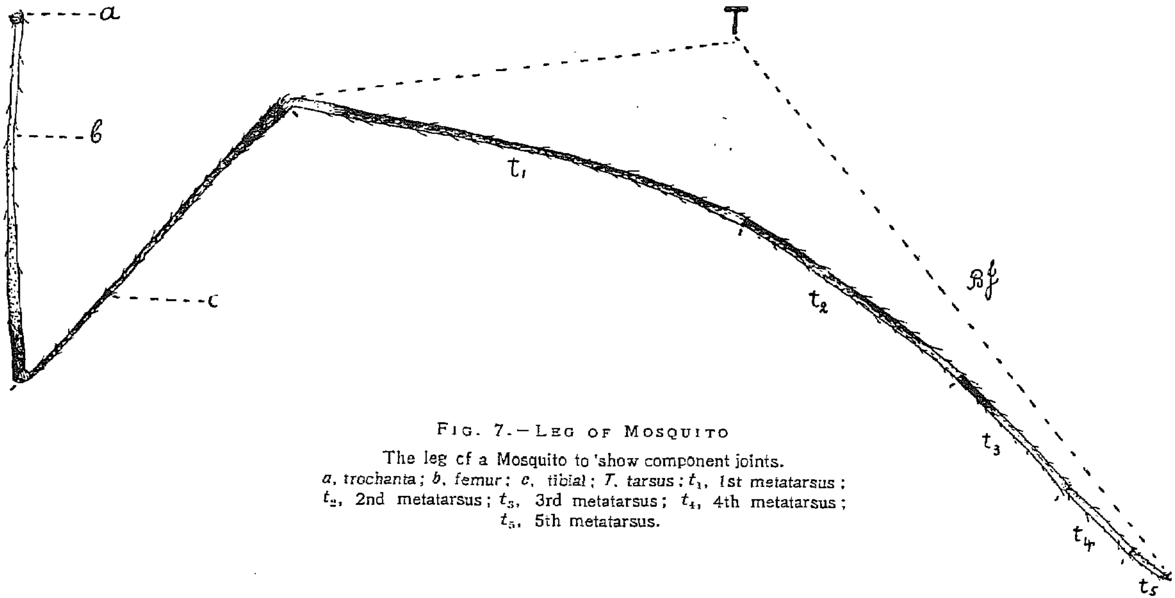


FIG. 7.—LEG OF MOSQUITO

The leg cf a Mosquito to 'show component joints.
a, *trochanta*; *b*, *femur*; *c*, *tibial*; *T*, *tarsus*; t_1, 1st metatarsus; t_2, 2nd metatarsus; t_3, 3rd metatarsus; t_4, 4th metatarsus; t_5, 5th metatarsus.

morphology each pleuron consists of an anterior sclerite or *episternum*, and a posterior sclerite or *epimeron*, the two being separated by the *pleural suture*. In mosquitoes and other insects, however, this simple condition is no longer evident owing to the sub-division of the sclerites and their ultimate fusion with other members. The exact anatomy of the pleuræ, however, is unimportant to the field worker, except in so far as it concerns the position of certain groups of hairs which are important in the identification of the species. The position of these hair-groups and their respective names are shown in *Fig.* 6, *page* 38. Ventrally, the pleuræ are connected by other sclerites, the *sternites*, which enclose and shield the under-surface of the thorax.

The meso-thorax supports the two wings, which are horizontally attached, one on each side. Just below the articulation of each wing is a short drumstick-like appendage called the *halter*. The halteres are attached to the meta-thorax and apparently serve some aerostatic function, for if they are amputated or are treated with a local anæsthetic such as cocaine, the insect loses its stability in flight and falls helplessly on its back when flight is attempted. The dorsal aspect of the post-scutellum below the scutellum is dome-shaped and in some species bears hairs which are characters of generic importance.

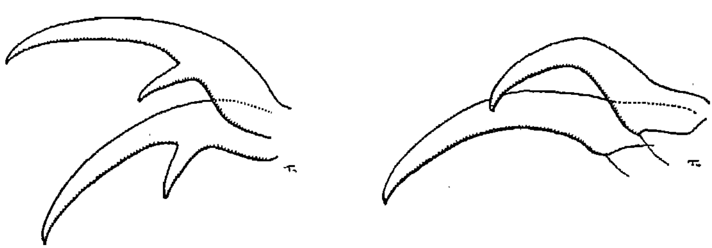


FIG. 8.—LEG CLAWS OF MOSQUITO, SITUATED AT TIP OF 5TH METATARSI
(After W. D. Lang. "A Handbook of British Mosquitoes")

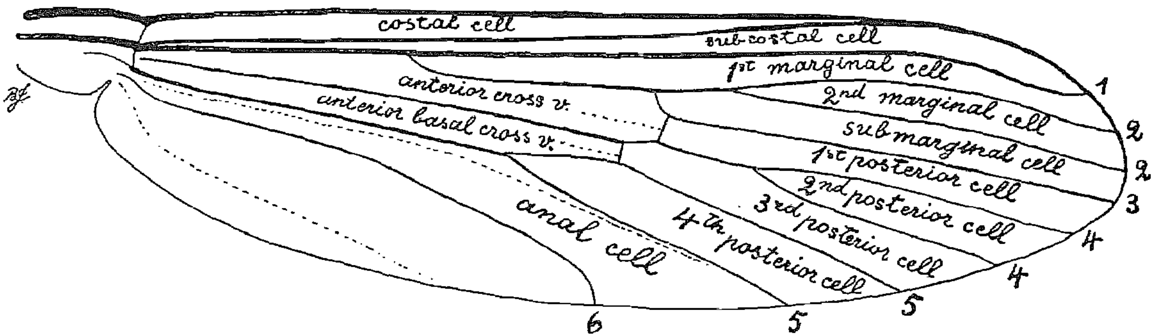


FIG. 9.—NOMENCLATURE OF MOSQUITO WING ANATOMY
1–6 veins and their branches

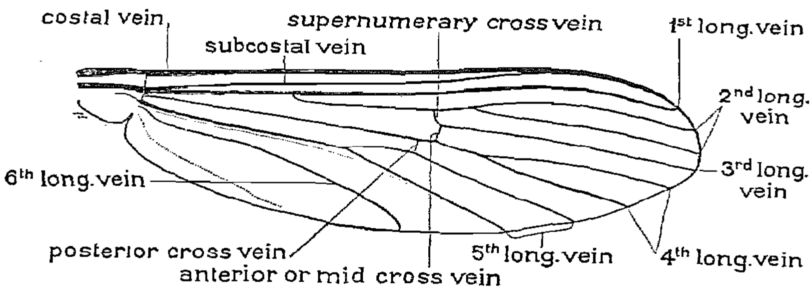


FIG. 9A.—NOMENCLATURE OF WING VEINS
(After W. D. Lang. "A Handbook of British Mosquitoes")

The Legs (*Fig.* 7, *page* 40) are attached to the under-surface of the thorax. The attachment of the three pairs of legs takes place by short conical protuberances called the *coxæ*. To each coxa is attached a very short and flexible joint termed the *trochanta* to which the rest of the leg is attached. Following the trochanta is a long joint known as the *femur*, to which is articulated distally another long joint, the *tibia*, and to it in turn is articulated the sub-divided *tarsus*. Each tarsus is made up of five much smaller joints, termed, respectively, the 1st, 2nd, 3rd, 4th and 5th *metatarsi*. The 5th metatarsus is generally quite short and carries two minute *claws* at its tip. The form of the claws is of considerable taxonomic value, as in some species the claws conform to recognised types—simple and toothed claws (*Fig.* 8, *page* 41). Between the claws are two microscopic structures which may be examined by suitably mounting the legs (*page* 221) for observation under the higher powers of the microscope. The two structures are called the *empodium* and the *pulvilli*. Both are found in some species, but in other species the pulvilli are absent. The empodium is a small structure, set between the bases of the claws, either in the form of a minute pad bearing numerous hairs, or it may be represented simply by a small tassel of hairs. The pulvilli are two pads of a much larger size, situated one on each side of the apex of the 5th metatarsus and underlying the claws (*see Fig.* 34, *page* 148). The hind pair of legs in mosquitoes is usually considerably longer than the front and middle pairs, and when the insect is at rest the hind legs are often raised from the surface on which the insect is resting, and are turned upwards, while at the same time they are slowly waved in the air. One function of the upturned legs is to fend off other mosquitoes when they attempt to settle too near an already occupied position. The legs of

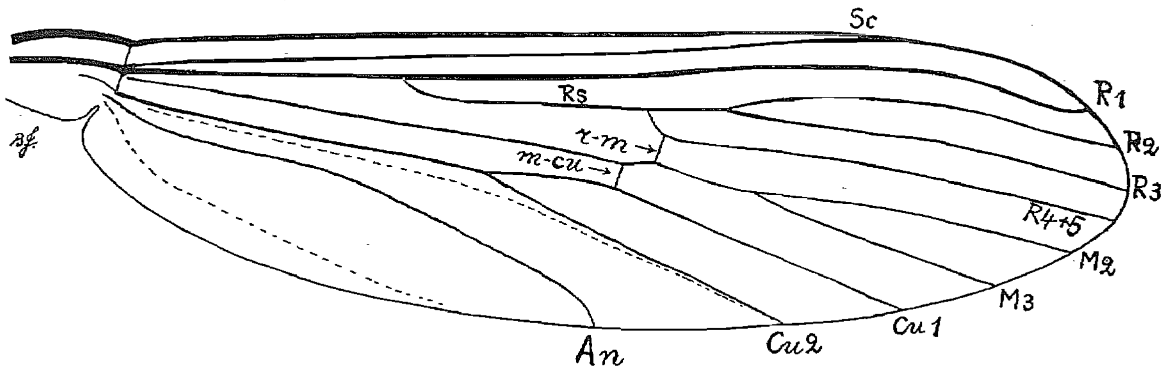


FIG. 10.—ALTERNATIVE NOMENCLATURE OF WING VENATION

mosquitoes are often clothed with coloured scales dispersed in distinct bands or patterns. The legs are, in any case, always scale-clad, and also bear scattered long and short hairs.

The Wings. The wings of mosquitoes are formed of a delicate transparent chitinous membrane supported by a characteristic arrangement of chitinous veins (*Fig.* 9A, *page* 42). The plan of the wing venation distinguishes mosquitoes from all other insects.

Reference to (*Figs.* 9 *and* 9A, *page* 42) will make the morphology and nomenclature of the wing clear. The whole margin of the wing is bordered by a vein which along the front margin is thick and extends in decreasing thickness around the wing-tip and rear margin. This vein is called the *costal vein* or, more briefly, the *costa.* On the inner side of the costal vein, and close to it, is a shorter vein which terminates in the costal vein before reaching the wing-tip. This is the *sub-costal* or *auxiliary vein.* Below the sub-costal vein, extending from the base of the wing to the apical portion of the wing, is the *1st longitudinal vein.* The *2nd longitudinal vein* springs from the 1st longitudinal vein and, after running as a single vein for some distance, bifurcates and runs as two separate portions which terminate separately in the costal vein at the wing-tip. The area enclosed by the two separate portions is termed the *2nd marginal* or *upper fork-cell,* and the preceding single section of the *2nd longitudinal vein* is termed its *petiole.* The *3rd longitudinal vein* has its point of origin near the middle part of the single portion of the 2nd longitudinal vein, from which it extends almost at a right-angle, and then by a bend (the *supernumerary cross-vein*) runs almost parallel to the lower portion of the 2nd vein to meet the costa at the rear curve of the wing-tip. The *4th longitudinal vein* originates from the base of the wing, bifurcating into two

portions after it has extended from the base about two-thirds of its total length, the two separate portions meeting the costa at respective points on the lower bend of the wing-tip. The area enclosed by the two separate portions is termed the *2nd posterior* or *lower fork-cell,* and the preceding single section of the 4th longitudinal vein is known as the *petiole* of this cell. A very small vein jutting out from the 4th vein at almost a right-angle connects the 3rd and 4th veins near the sharp bend which the 3rd vein makes before its connection to the 2nd vein. This small vein is called the *anterior* or *mid cross-vein*; and since, in some species of mosquitoes, its length, its actual point of contact with the 3rd vein, and the angle it makes with the 3rd and 4th veins are variable, the anterior cross-vein is an important identification character. The *5th longitudinal vein* originates at the base of the wing and bifurcates about its middle to form two portions which meet the costa separately on the rear margin of the wing. By a distinct forward bend the first portion of the 5th vein approaches the 4th vein and is connected to it by another very short vein which meets both longitudinal veins almost at a right-angle. This small vein is called the *anterior basal* or *posterior cross-vein,* and it also forms an important identification character, as the relative positions of the two cross-veins differ in many species. The *6th longitudinal vein* has its point of origin in the base of the wing, and extends as a single vein to meet the costa near the middle of the rear margin of the wing. The spaces of the wing membrane enclosed by the several veins are distinguished by special names, which will be seen by reference to *Figs.* 9 *and* 9A, *page* 42, and an alternative nomenclature of the wing venation which is used by some authors is given in *Fig.* 10, *page* 44.

Under fairly high magnification the wing membrane of many species of mosquito may be

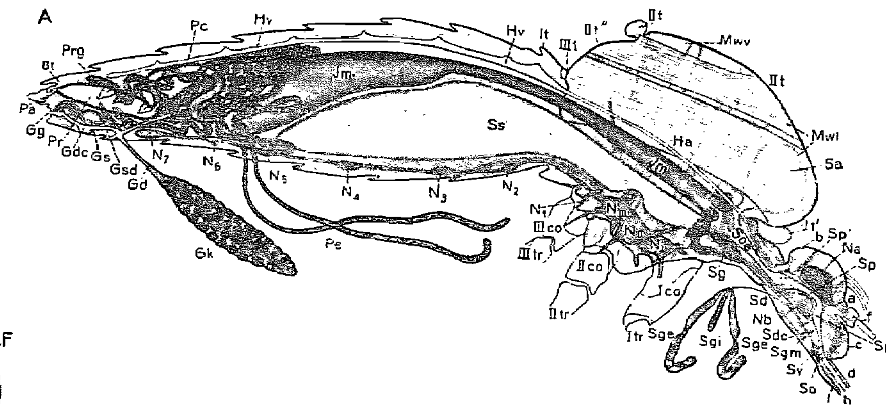
seen to bear minute hairs on its surface. These microscopical hairs are termed the *microtrichia*. Owing to the fact that the wing veins of all species of mosquitoes are decorated with either uniformly-coloured or vari-coloured scales, and that in some species these scales are large and very numerous, it is often difficult to observe the complete venation pattern unless the scales are first removed, and the veins themselves stained (*see page* 220).

Before turning from the consideration of the thorax and its appendages, it should be noted that just below the ventral margin of the rounded dorsal surface of the meso-thorax, above and almost in line with the point of attachment of the first pair of legs, there are two slit-like respiratory openings in the lateral aspects of the meso-thorax, one on each side, situated just behind the pro-tuberances of the pro-thorax. These are the *pro-thoracic stigmata*. Two similar structures occur above the points of attachment of the hind pair of legs, below the dome-shaped post-scutellum and near the bases of the halteres, and these are termed the *meta-thoracic stigmata*.

In certain species of mosquitoes—none of which have so far been found either in Mauritius or Rodriguez—a group or groups of hairs occur on the dorsal surface of the post-scutellum.

The Abdomen. The abdomen of mosquitoes is composed of ten segments, but only the first eight segments are readily seen. Each segment consists of a dorsal chitinous plate *(tergite)* and a ventral chitinous plate *(sternite)* connected laterally by unchitinised cuticle. The side-walls of the abdomen are thus elastic and permit considerable distension, as is necessary when the insect feeds. The last two segments are modified to form the external genitalia, and are to some extent telescoped into the 8th segment. On the lateral aspects of the segments *abdominal stigmata* occur as slit-like

A



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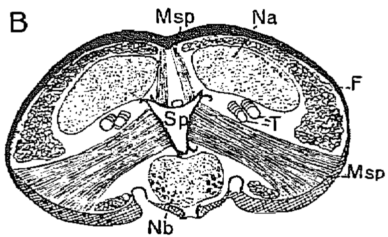


Fig. 11.—Internal Anatomy of *Anopheles bifurcatus*

A. Longitudinal section of female ; **b**, transverse section of head ; **c**, frons ; **d**, labrum : **f**, antenna : **h**, proboscis : **l**, labium ; **Ha**, thoracic muscles ; **Na**, supra-œsophageal ganglion (brain) : **Nb**, sub-œsophageal ganglion ; **It′**, prothorax : **Sa**, œsophageal diverticula ; **Sd**, salivary duct ; **Sgi**, salivary glands ; **Sp**, pharynx ; **Sp,″** pharyngeal-pump ; **Ss**, ventral œsophageal diverticulum ; **Iit**. thorax ; **Ut**, scutellum ; **Ut″**, metanotum ; **Jm**, œsophagus ; **Jm′**, stomach ; **Pc**, hind intestine ; **Pe**, Malpighian tubules ; **Pa**, anus ; **Pr**, rectum ; **Gk**, ovary ; **NI**-$_{33}$. **NI-N**$_7$; **T**, tracheæ ; **F**, eye ; **Msp**, head muscles. (After E. Martini, "Lehrbuch der Medizinischen Entomologie")

apertures situated in the membraneous side-walls of the abdominal segments. There is a pair of stigmata to each of the segments, one on each side. The abdomen is often completely clothed with overlapping flat scales and long hairs, but in many of the anopheline species the scale vestiture of the abdomen is much reduced, and may only be in the form of clumps of projecting scales. The external genitalia, as previously mentioned, furnish a reliable character for the separation of the sexes. The male genitalia consists of an elaborate organ formed by a modification of segments 9 and 10 which projects from the 8th segment. It is easily recognised by the pair of claws *(claspers)* whose function is to grip the tip of the female abdomen. The external genitalia of the female are inconspicuous, and are only visibly represented by the two small rod- or leaf-like *cerci.* The cerci are tactile organs and, among other functions, are used in oviposition to orientate the egg before it is laid.

The abdomen of the male mosquito is usually longer, more slender and more hairy than that of the female of the same species, and in the male the abdomen terminates rather bluntly, whereas in the female the termination is more or less pointed.

The Internal Anatomy of Mosquitoes (*Fig.* 11, *page* 48, *and Fig.* 12, *page* 50). As we have already seen, the apposition of the labrum-epipharynx and hypopharynx of the proboscis forms a duct (*page* 35). This duct opens at the base of the proboscis into a short pharynx (buccal cavity)[1] in the form of a short membraneous tube which expands near the middle of the head into a pear-shaped sac termed the *œsophageal pump.*[2] Muscles are attached to the

[1] & [2] I am informed by Mr. B. Jobling, of the Wellcome Bureau of Scientific Research, who has made an extensive study of the homology of the mouth-parts of the *Diptera*, that in the case of the mosquitoes the commonly used term "buccal cavity" should be replaced by the word "pharynx," and similarly, "œsophageal pump" should replace the term "pharyngeal pump."

walls of this sac and by their action the blood or plant sap is pumped up the proboscis and driven into the tubular *œsophagus*, which extends from the rear end of the *œsophageal* pump for a short distance into the anterior portion of the thorax.

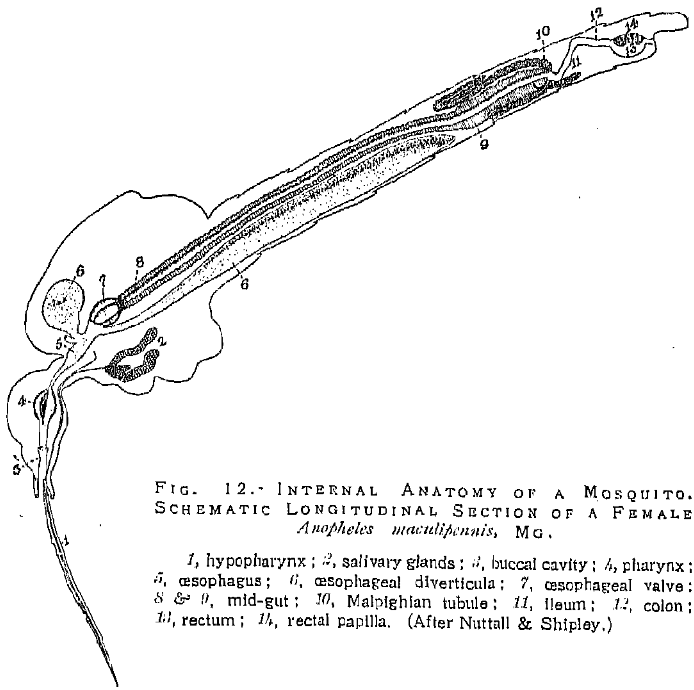


FIG. 12.- INTERNAL ANATOMY OF A MOSQUITO. SCHEMATIC LONGITUDINAL SECTION OF A FEMALE *Anopheles maculipennis*, MG.

1, hypopharynx; *2*, salivary glands; *3*, buccal cavity; *4*, pharynx; *5*, œsophagus; *6*, œsophageal diverticula; *7*, œsophageal valve; *8* & *9*, mid-gut; *10*, Malpighian tubule; *11*, ileum; *12*, colon; *13*, rectum; *14*, rectal papilla. (After Nuttall & Shipley.)

At this point two large diverticula arise from the œsophagus. These are the *œsophageal diverticula*. The smaller of the two, the *dorsal œsophageal diverticulum*, lies in the anterior portion of the thorax above the œsophagus, and the larger, the *ventral œsophageal diverticulum*, runs backwards

through the thorax and into the abdomen as a long thin-walled sac situated immediately below the mid-gut.

Near the origin of the diverticula, the œsophagus enters the pyriform enlarged anterior end of the mid-gut, which is called the *œsophageal valve*. This valve controls the entry and escape of fluids destined to the mid-gut. It also seems to control the passage of fluids into the œsophageal diverticula. These diverticula are often called the food reservoirs. Food reservoirs they certainly are, but in my experience they have never been found to contain blood. They seem to function solely as reservoirs of fruit sap and water. This may be easily demonstrated by permitting a hungry mosquito to feed on blood in the normal way, and when it is nearly but not quite replete, removing the mosquito from the skin and presenting it with fruit sap on which to satiate its appetite. If the insect is then dissected, it will be found that although the stomach is not fully distended, all the sap which has been imbibed is stored in, and probably fully distends, the diverticula. The experiment may be reversed with another mosquito by presenting it first with sap, and later with a blood meal, when it will again be found that the sap goes into the diverticula and the blood into the stomach. There can be little doubt that the sap ultimately is taken into the stomach in the process of digestion, but it seems that the sap enters the stomach only in small quantities at a time.

The *salivary glands* lie in the thorax just above the attachment of the first pair of legs, and immediately under the œsophageal valve. Mosquitoes possess a pair of salivary glands each composed of three sausage-shaped members or *acini*. Two of these acini are long, and the third, situated between the other two, is short, the cells and contents of which are more refractile. The

acini are glands composed of secretory cells arranged around a central canal or *lumen*, termed the *intra-acinal duct*. These ducts unite at the anterior ends of the glands to form a single duct from each of the composite organs, and the two *salivary ducts* pass from the thorax along the ventral wall of the neck into the head, where they unite before passing through the membraneous *salivary-pump* (situated at the base of the hypopharynx) which delivers the saliva through the minute duct in the hypopharynx.

From the rear end of the œsophageal valve the *mid-gut* extends as a simple thick-walled tube to the *stomach* which, when it is empty, lies within the 5th and 6th abdominal segments.

The stomach is an extremely elastic sac and is capable of great distension. In a fully-fed mosquito the whole abdomen is ballooned to such an extent that the red colour of the ingested blood can be seen through the abdominal walls, and the weight of the insect is so greatly increased that it often finds flight difficult. In the stomach the blood is rapidly altered. The main portion of the plasma is excreted in the form of droplets, which are projected from the body with considerable force. This begins very soon after the insect commences to feed, probably to permit the mosquito to take up as much of the solids of the blood as possible. The excretion of plasma continues for some time after the insect has left its host, and the blood within the stomach turns black and may within 36 hours be completely digested. A fertilised mosquito may be content with one full meal on which to develop her ova, but frequently additional meals are taken even within 24 hours of the first meal. Hence an additional danger from malaria-infected mosquitoes.

At the posterior end of the stomach there is a slight dilatation into which the five Malpighian

tubules open. The *Malpighian tubules* are long slender tubes of a semi-opaque white colour, and are composed of large excretory cells surrounding a minute central lumen. The tubules are closed at their free extremities, but the central lumina open into the intestine at their bases. The apparent function of the Malpighian tubules is analogous to that of the kidney in vertebrates, namely, the collection of the waste products from the blood of the body-cavity. From the seat of attachment of the Malpighian tubules to the intestine, the intestine continues as a short slender tube, termed the *hind-gut,* which lies enclosed by the 7th abdominal segment. Within the 8th segment the hind-gut is dilated to form the *rectum.* On the inner surface of the dorsal wall of the rectum are six ovoid *rectal papillæ,* which are easily seen, but whose function is unknown.

The Respiratory System. The adults, like the larvæ and pupæ, breathe by means of a complex system of air-tubes, the *tracheæ,* which ramify throughout the body. Each tissue-cell has its own minute air-tube or *tracheole,* and, by the connection of each tracheole to a larger *parent stem* and the subsequent connection of the parent stems to larger tracheæ, the whole system is ultimately joined to the two main dorsal tracheæ which run longitudinally in the body of the insect. The dorsal tracheæ gain access to the air through openings in the body-wall, called *spiracles* or *stigmata.* Spiracles occur both on the thorax and abdomen. The thoracic spiracles consist of two pairs, the respective members being situated on each side of the meso-thoracic and meta-thoracic segments. Of these the anterior one is the largest in the body. The abdominal spiracles are situated in the elastic membrane, one on each side of the abdominal segments. The oxygen of the air

required for respiration purposes, and the waste gases from the tissues of the insect, find their way in and out of the tracheal system partly by gaseous diffusion, and partly by the pressure exerted on the tracheæ by the contraction of the body muscles. The action of the heart between the two main dorsal tracheæ causes a rhythmical lateral movement of these tracheæ, and thus maintains an active gaseous current.

The Circulatory System. Mosquitoes, in common with all other insects, have no closed blood-system comparable with the blood-system of vertebrates. There is a simple *heart* in the form of an elongate membraneous sac lying below and between the two dorsal main tracheæ. The heart is equipped with a row of *ostia* or *valves* which open laterally into the body-cavity. The peristaltic contraction of the heart from the posterior to the anterior end drives the blood collected during diastole in a forward direction, causing a desultory circulation in all parts of the body-cavity. The *blood* itself is a colourless serum, and contains a considerable number of *phagocytic cells* which seem to play a similar rôle to the white-cells of vertebrate blood.

The Nervous System. The nervous system of mosquitoes, in conformity with that of the Insecta in general, consists essentially of a chain of paired ganglia distributed along the ventral median line of the body-cavity. Each pair of ganglia is connected to form a chain by paired longitudinal nerve chords *(connectives)*, and the ganglia of each separate pair are connected by transverse chords termed *commissures*. There is a pair of ganglia to each segment of the body, but the members of the pair are so closely united that they often appear as a single ganglion. In the head, due to the compression and fusion of the composite segments,

the ganglia are fused to form nerve centres of complex form. Such compound ganglia are termed *ganglionic centres*. In the central nervous system of insects, with its distinct controlling centres *(ganglia)* along the whole length of the body, we have a system in many ways quite unlike the nervous system of vertebrates.

The head contains two ganglionic centres : the *supra-œsophageal ganglion,* often termed the *brain,* lying near the middle of the head ; and the *sub-œsophageal ganglion* which lies appressed to the rear ventral surface of the head cavity. The connectives joining these two cephalic ganglia are arched from each other sideways, and between them, through the gap thus formed, the œsophagus passes to its connection with the pharynx. In other words, the supra-œsophageal ganglion, or brain, is the only part of the insect nervous system which lies above the alimentary system.

From the supra-œsophageal ganglion large masses of nerve tissue are connected by nerves to the antennæ, the compound eyes, and to the other sense organs of the head, while nerves are distributed from the remainder of the ganglionic chain to the muscles and organs in each of the body segments separately controlled by these ganglia.

In consequence of this subdivided central nervous system, the death of an insect is often not immediately brought about by injury or destruction of any one part of the body. A mosquito may be capable of flight with more than half of its abdomen destroyed, or even after it has been decapitated.

THE SENSE ORGANS : SIGHT. Mosquitoes possess fairly acute sight, but little is known regarding their exact range of vision. From the fact, however, that mosquitoes in the Tropics, will

instantly recognise the stealthy approach of "jumping spiders" at a distance of more than 18 inches and may elude capture by immediate flight, it would seem reasonable to suppose that they have clearly seen the approaching enemy from that distance. Mosquitoes in flight may be observed to avoid obstacles in their path extremely well, though it has been suggested that the insects "sense" the obstacles by reflected sound vibrations and deflected air currents—a rather unsatisfactory assumption, as all insects in flight will collide with a piece of transparent glass placed in front of them. Anyone who has watched the activities of "swarming" mosquitoes in a field or garden, or has studied the aerial manœuvres of predaceous *Empidæ* and *Asilidæ* (two other Families of the *Diptera*) in the capture of their prey, will feel certain that the compound eyes of the *Diptera* are organs of remarkably accurate vision.

The eyes of mosquitoes have been said to be concerned mainly with near vision. No doubt near vision is an essential requirement, but it is astonishing to the observer, if near vision is the main purpose of the large compound eyes, how extremely stupid these insects frequently are in selecting an appropriate part of their hosts for a blood meal. Observations would make it seem more probable that the selection of the appropriate site depends not so much on near vision as on the reception of tactile sensations derived from the palpi and proboscis.

Tactile Sense. A hungry mosquito, after it has settled on the skin of its host, may be seen to select the site of puncture by rapidly touching the skin in several places with the tip of the proboscis.

At the same time, particularly in the case of anopheline mosquitoes, the palpi are vibrated over the area of skin which is being searched. Radiant

heat from the skin surface can be shown to make the site selection easier to the insect, probably on account of the fact that heat favours the olfactory sense. An area of skin chilled by the application of ice in a non-porous container, has been shown to delude hungry mosquitoes into thinking that no blood supply is available. The sight of the skin was not in itself sufficient to induce them to search for food.

THE OLFACTORY SENSE. In many ways it can be demonstrated that mosquitoes have a highly developed olfactory sense. For instance, if into a cage of starving mosquitoes which are quietly resting on the sides, a small quantity of warm defibrinated blood is introduced in such a manner that the insects are not disturbed, they will very rapidly become aware of the food supply and partake of it with avidity. Similarly, if nectar-containing flowers or moistened dried fruit, or, in the case of thirsty mosquitoes, merely water, is cautiously brought into the cage, the insects will very soon appreciate the presence of the desired materials.

THE AUDITORY SENSE. Mosquitoes have what may be regarded as a well-marked auditory sense. Resting mosquitoes are readily disturbed by sounds of a particular pitch. The sharp bang emitted by the explosion of small quantities of nitrogen iodide will disturb resting mosquitoes at a considerable distance. Certain musical notes of high pitch emitted from tuning-forks, or from electrical apparatus through which low-frequency alternating currents are flowing, have been observed to attract large numbers of male mosquitoes. The auditory organs of insects are termed the *chordotonal organs*. In mosquitoes the chordotonal organs are principally situated in the antennæ.

Other Sense Organs. While it is permissible perhaps to regard the senses of sight, hearing and smell in insects as probably comparable with the equivalent senses in higher animals, it must not be overlooked that, at least in relation to what we term the auditory and olfactory senses of insects, it may be arrant presumption on our part to make such a comparison. The sensations produced by the stimuli may be totally dissimilar to anything we know from reactions set up by these stimuli in our own sense organs.

Moreover, insects, including mosquitoes, are known to possess several sense organs whose functions are not comprehended.

From experimental evidence it seems clear that the halteres are highly developed aerostatic sense organs of some sort, and many parts of the chitinous integument contain minute sensory cells *(sencillæ)* whose functions have not yet been satisfactorily explained.

The Fat-Body. This is a fat-storage tissue and is distributed in many parts of the insect's body. It chiefly occurs, however, immediately under the chitinous integument of the thorax and abdominal segments, and attains its greatest development in fully-grown larvæ and hibernating female mosquitoes. The fat-body evidently supplies a nutrition reserve in the larva for the pupation period, and in the adult (among the species which pass the winter as adults) to carry it over the winter when climatic conditions prevent the normal activities of the insect. The fat-body is also an interesting tissue, since in many parts of the world it becomes infected with several species of Sporozoa of the Genus *Thelohania*, etc., which bring about a fatal and infectious disease among mosquito larvæ.

The Reproductive Organs. MALE. The reproductive organs of the male mosquito consist of a pair of tubular *testes* from which the *Spermatozoa* pass by ducts termed the *vasa deferentia* to the sperm reservoirs, the *vesiculæ seminales*, and thence via a common duct, the *ductus ejaculatorius*, to the external genitalia. The *external genitalia* of the male (*Fig.* 13, *page* 60) is a complex structure termed the *hypopygium*, and is formed by a modification of the 9th and 10th abdominal segments. According to Edwards, the word " hypopygium " is used to denote all the structures representing the ninth and tenth segments of the abdomen, and is composed of four parts :—

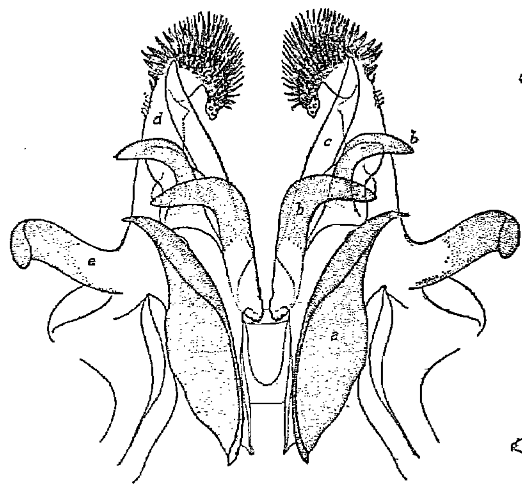
" 1. A more or less continuous chitinous ring, representing the ninth abdominal segment. The tergite often has a pair of processes, *the lobes of the ninth* tergite. These lobes should be dorsal in position, but shortly after the emergence of the adult, the tip of the abdomen undergoes torsion through an angle of 180 degrees. The lobes of the ninth tergite are therefore the most ventral parts after the torsion.

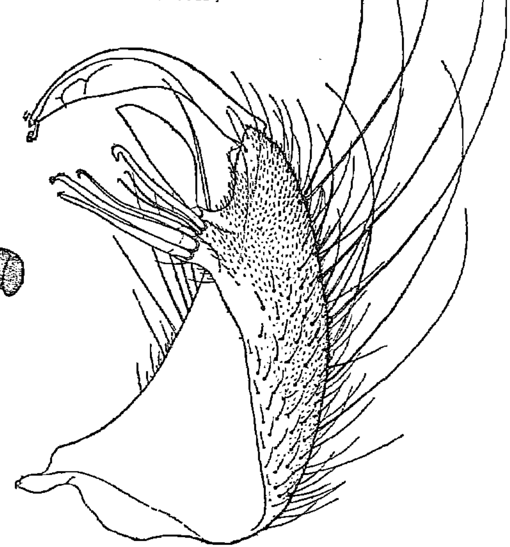
" 2. A pair of large appendages of the ninth segment, the *side-pieces*, having at their tips the *claspers*. The side-pieces develop *basal* and *apical* lobes in several genera. In the *Aëdes* group the side-piece has a median unchitinised groove extending to the tip between a chitinous upper and lower flap. The lobes on the side-piece develop here on the lower flap ; the upper has a modification at its base that develops into a distinct organ, the *claspette*. In the *Culex* group this median groove is absent, but there is a more or less triangular part of the median wall not chitinised and slightly excavated. At the tip of this triangle there is a lobe bearing spines and filaments.

" 3. *Anal chitinisations*. Originally dorsally placed compared with the genital chitinisations,

FIG. 13.—*Culex trifilatus*, sp. n.

Basal parts of hypopygium from above, highly magnified; right side-piece of hypopygium, inner side view, enlargement about half that of the basal parts; *a*, unci; *b*, first, *b'*, supplementary, and *c*, second division of the harpagones; *d*, harpes, with crowns of spines: *e*, basal projection of the harpes. (After F. W. Edwards.)





they become ventral (lower) in position after the torsion. The anus is placed at the tip of the tenth segment. The *tenth sternites* are usually strongly chitinised and conspicuous. In anopheles, the tenth segment is still completely membraneous.

"4. *General chitinisations.* The genital tube opens between the ninth and tenth sternites; its apical part is chitinised. This chitinous structure, as a whole, bears the name of *ædeagus.* As a rule, it is possible to distinguish the following parts:—

"a. *Basal plates.* Chitinous plates of various size lying within the ninth segment, often extending back into the eighth. They articulate with a process that arises from the base of the outer chitinous wall of the side-piece, the *apodeme.* Often the apodeme only touches the basal plate with its point; sometimes it is fused with the plates over a certain distance.

"b. *Parameres.* The apex of the basal plate connects with a paired chitinous organ near the median line at the base of the ædeagus. These organs are the *parameres.* They are the connecting link between basal plates and

"c. *The mesosome.* The *mesosome* is a complicated body lying between and distal to the parameres; it is a thickening of the wall of the distal part of the ædeagus. The lateral portions are most distinct. They may be connected by chitinous *upper* and *lower bridges.* The mesosome may be tubular, as in anopheles, or consist of only a pair of rods, but sometimes it is split up in a large number of *plates,* reaching its highest development in *Culex.*"

C. Bonne and J. Bonne-Wepster. *Mosquitoes of Surinam.*

The form of the external genitalia of male mosquitoes is strikingly different among the separate genera and species, and is therefore of considerable taxonomic importance.

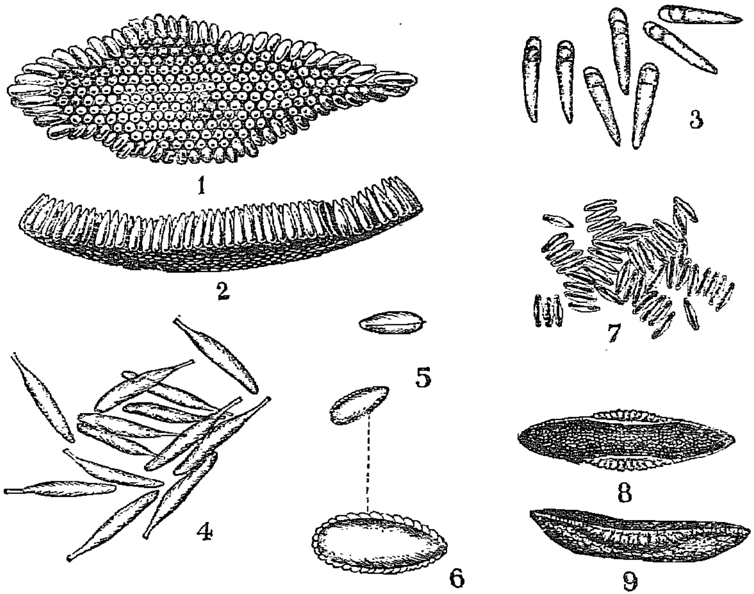


FIG. 14.—VARIOUS FORMS OF MOSQUITO EGGS

1, Egg-raft of *Culex*, seen from above: 2, same side-view (after Sambon); 3, separate *Culex* eggs; 4, eggs of Panoplites (after Daniels); 5, eggs of Stegomyia: 6, the same, more highly magnified (after Theobald); 7, groups of anopheles eggs (after Sambon); 8, egg of *Anopheles maculipennis*, showing lateral floats, seen from above; X30, diams.; 9, the same, viewed laterally (after Nuttall)—from "Gnats or Mosquitoes," by G. M. Giles.

FEMALE. The reproductive organs of the female mosquito consist of a pair of *ovaries* composed of numerous follicular tubes containing the egg-follicules. *Oviducts* descend from each ovary and unite to form a common oviduct into which open the ducts from the *spermathecæ* or *sperm reservoirs*. The *spermathecæ* are small spherical organs, usually three in number and so heavily chitinised that they form conspicuous objects when the mosquito is dissected. They lie enclosed by the eighth abdominal segment. Into the oviduct there also open ducts from other small glands called the *collecterial glands* or *cement glands*, whose function is to provide the eggs of some species with the necessary cementing substance for the formation of egg-rafts. The common oviduct opens into the *bursa copulatrix* situated within the tenth segment and flanked exteriorly by two tactile papillæ, the *cerci*.

GENERAL LIFE-HISTORY OF A MOSQUITO

The life-history of a mosquito is now well-known in all parts of the world, even by many people not concerned with control measures. Nevertheless, it will be well briefly to outline the story once more.

Unlike some other insects, all the species of mosquitoes develop from eggs, and these eggs are invariably laid either directly on the surface of water, or on damp surroundings in contact with water. Mosquito eggs are, naturally, minute objects ranging in size from about 1 mm. to 4 mm. in length. The differences in the shape and structure of the eggs of the different species are usually striking, and to the mosquito expert this is of great value in the provision of specific characters (*Fig*. 14, *page* 62). All mosquito eggs are laid in one of three different ways: (1) either they are oviposited separately, but are arranged by

the female in the act of oviposition into an adherent mass in cigar-shaped bundles to float on the water-surface like tiny rafts ; or (2) they are oviposited separately and are laid singly on the surface of the water, each egg being provided with lateral floats or other hydrostatic structures, which enable the egg to float safely, resisting submersion; or (3) the eggs are laid singly on damp surroundings or on the water-surface, to sink or float as Fate ordains, but usually the embryos within such eggs are able to withstand submersion without harm, and when they hatch from the eggs, the larvæ can even wriggle out of a layer of mud or closely packed vegetable detritus to reach the surface of the water. The eggs of some species can resist desiccation for long periods, this being especially true of the species whose normal breeding-places are small collections of water such as rain-containing gutters, and holes in the ground or in trees where the water is prone to dry up. In localities where there are dry seasons extending over a period of months, many species of mosquito survive the drought in the egg stage.

Under conditions favourable to rapid development, mosquito eggs hatch within from 3 to 5 days of their being laid, and the first stage—or as it is perhaps preferably termed, the 1*st instar*—larvæ emerge as minute colourless and almost transparent creatures 1 mm. or less in length. The complete larval period, when conditions are favourable, may be passed through in as short a period as from 5 to 7 days, while under adverse conditions, or if the particular species passes the winter in the larval stage, the larval period may continue for many weeks or even months (*see pages* 143-145). Soon after emerging from the eggs, the bodies, and especially the heads of the larvæ, darken, and by close observation they may be seen swimming through the water in all directions. As 1*st instar larvæ,* they obtain most of the oxygen

needed for respiration purposes by direct absorption of the dissolved oxygen in the water. The 1st instar larvæ feed and grow rapidly, and in situations with a high atmospheric temperature they shed their skins within 24 hours, the larvæ then becoming what are known as *2nd instar larvæ*. At this stage they are somewhat darker and much more easily seen in the water, being provided with most of the structural characters pertaining to the particular species to which they belong. As soon as the skin has been shed the larvæ begin feeding once more, and the 2nd instar lasts for a variable period depending upon the temperature of the water and the supply of food available. When the larvæ have reached the end of the 2nd instar the skins are again shed and the larvæ then become *3rd instar larvæ*. Once more the larvæ continue to feed and grow, and within a variable period shed their skins a third time, then becoming *4th instar larvæ*. After a further period of feeding and growth, the 4th instar larvæ cease to feed and become sluggish. The muscles and other parts of the head discontinue to function and, from a previously semi-transparent condition, the bodies of the larvæ develop an opacity—usually of a yellowish colour.

They can still swim actively if disturbed, but prefer to lie quietly either at the surface of the water or at the bottom, slowly bending their bodies from side to side. After an interval of an hour or so, sometimes almost explosively, the larval skin suddenly ruptures across the head and thorax and an excited comma-shaped creature escapes from the skin. This is the *pupa*—a very different organism to the larva. The pupa does not feed, and represents the chrysalis stage of the mosquito. Unlike the larva, the pupa's sole object in life is to rest quietly at the water surface, taking in air through the two conspicuous respiratory organs

called the *respiratory trumpets* or *thoracic stigmata*, which are situated on each side of its "head"—*cephalo-thorax*, so-called from the fact that this part of the pupa encloses the head and thorax of the developing mosquito. The pupa can dive and swim actively, however, by means of its flexible abdomen and fan-shaped tail *(the telson)*, and, in order to escape danger, it may remain submerged hidden behind weeds or fallen leaves at the bottom of the containing dish or on the floor of its normal breeding-place. When it first emerges from the skin of the 4th larval instar, the pupa is often semi-transparent, and in the case of some species it is of a brilliant green or yellowish-green or black colour. As it gets older the colour darkens and at the same time it becomes progressively more buoyant until it can remain below the surface only with difficulty. Usually from 3 to 5 days after the pupa makes its appearance the adult mosquito emerges from the *puparium* or pupal case. If the most buoyant pupæ are kept under observation about this time, it will ultimately be seen that the pupæ repeatedly stretch out their abdomens parallel to the water-surface. This is the first sign that the mosquito within the puparium is preparing to release itself. While the abdominal extensions are taking place, it will be noticed that longitudinal lines and patches of a silvery colour are appearing under the integument of the cephalo-thorax. This is due to the formation of air-spaces between the walls of the puparium and the body of the mosquito, so that all parts of the mosquito are detached from contact with the inner walls of the puparium by a layer of air. The air for this purpose is obtained by the pupa through the respiratory trumpets and is forced through the thoracic and abdominal stigmata of the imprisoned mosquito. At last the pressure of the air within the puparium and the muscular contractions of the mosquito cause the

puparium to rupture longitudinally across the dorsal surface of the cephalo-thorax, and the two sides of the puparium open outwards to rest on the water-surface as the upper aspect of the thorax of the mosquito protrudes from the opening. Gradually the thorax of the mosquito rises steadily out of the puparium, while temporarily the head of the mosquito is bent under the thorax. When the whole thorax has emerged, the head is suddenly lifted upwards and forwards into its normal position, The slow elevation of the mosquito from the puparium continues, and the legs, pressed together and projecting backwards under the body of the mosquito, are slowly withdrawn until the front pair is lifted clear and placed on the water-surface, one on each side of the puparium. The stability of the floating mosquito is thus strengthened, and both other pairs of legs are then similarly lifted from contact with the puparium and placed on the water. The mosquito now stands on the water-surface with the puparium under it, and the insect usually rests for a few minutes before the tip of the abdomen is also finally withdrawn from the puparium. Another rest of a few minutes is made, and then, very stiffly, the mosquito walks over the water and climbs up some convenient weed or up the edge of its breeding-place. Some species are capable of flight immediately afterwards, but the majority of species rest quietly for some time until the exo-skeleton and the wing-veins and membranes have hardened in the air. The specific markings in all their detail are consequently not evident until some hours after the emergence of the mosquito from the pupal-case. Among a batch of pupæ which have developed from the same batch of larvæ it will always be found that the males are the first to emerge, doing so generally from 6 to 24 hours in advance of the females. Consequently, with fully active males in existence, fertilisation of

the females often takes place as soon as the latter are capable of flight, and it will be observed, in the case of some species, that many males for this reason congregate in the vicinity of the breeding-places. The proportion of the sexes is nearly equal.

Both male and female mosquitoes feed. The males, however, confine their diet exclusively to plant saps and exudates, and the females, while partaking of this diet also, unfortunately, demand meals of blood before they can mature their eggs. Some doubt exists as to whether the females of all species find a blood-meal essential for this purpose, especially in regions of the world where mosquitoes are abundant and a source of blood is apparently scarce. Nevertheless, birds and small animals must not be overlooked as possible hosts, and I have, myself, in semi-desert regions of Africa, seen small rodents mercilessly attacked by mosquitoes. Moreover, it is generally found in such regions that, when man enters, he is himself keenly sought by the mosquitoes, which is sufficient evidence that the insects are quite familiar with the blood of vertebrates. On the other hand, it is well to keep in mind that there are one or two examples of mosquitoes whose proboscides are apparently not adaptable to the operation of puncturing an animal's skin, and that among this small group probably blood does not constitute any part of the diet of the females.

Twelve to twenty-four hours after the female mosquitoes of the blood-sucking group have emerged from the pupal state they actively seek a blood-meal. After feeding until the stomach is fully distended with blood, and the walls of the abdomen are so ballooned and thinned by the distension that the blood-containing stomach can be seen as a cherry-red sac, the female flies away to some sheltered retreat where she can quietly rest and develop her eggs. If the mosquito has been

fertilised before it partook of the blood-meal, as the blood is digested, the black colour of the abdomen slowly disappears, and changes to an opaque white or yellow due to the proliferation of the ovarian cells and the maturation of the ova. In warm climates the blood is completely digested in from 30 to 48 hours, and shortly afterwards the female then flies off to a suitable breeding-place to lay her eggs, which she deposits either singly or in a compact raft. In all cases the eggs are extruded from the abdomen separately, but in the raft-forming species the eggs are sticky when first laid, and are arranged by the parent so that they stand vertically with the sides of adjacent eggs adhering to one another.

An Outline of the Morphology and Internal Anatomy of the Egg, Larva and Pupa

The Egg. All mosquito eggs, whether they are laid singly—with or without hydrostatic structures—or are laid adhering together to form raft-like bundles, are essentially the same. Within the egg is the yolk and the embryonic cells; surrounding this is a delicate membrane termed the *vitelline membrane*, which is in turn surrounded by the hard chitinous egg-shell, the *chorion*, and enveloping the chorion is a very delicate membraneous coat termed the *enveloping membrane*. It is a development and modification of the enveloping membrane which forms the conspicuous "floats" on the ova of anopheline mosquitoes. All mosquito eggs are blunter at one end than at the other. On the under side of the blunter end a minute darker area is visible through the silvery enveloping membrane, which is the site of a minute hole in the chorion, called the *micropile*, through which the spermatozoon passes to fertilise the egg. Drab colours and

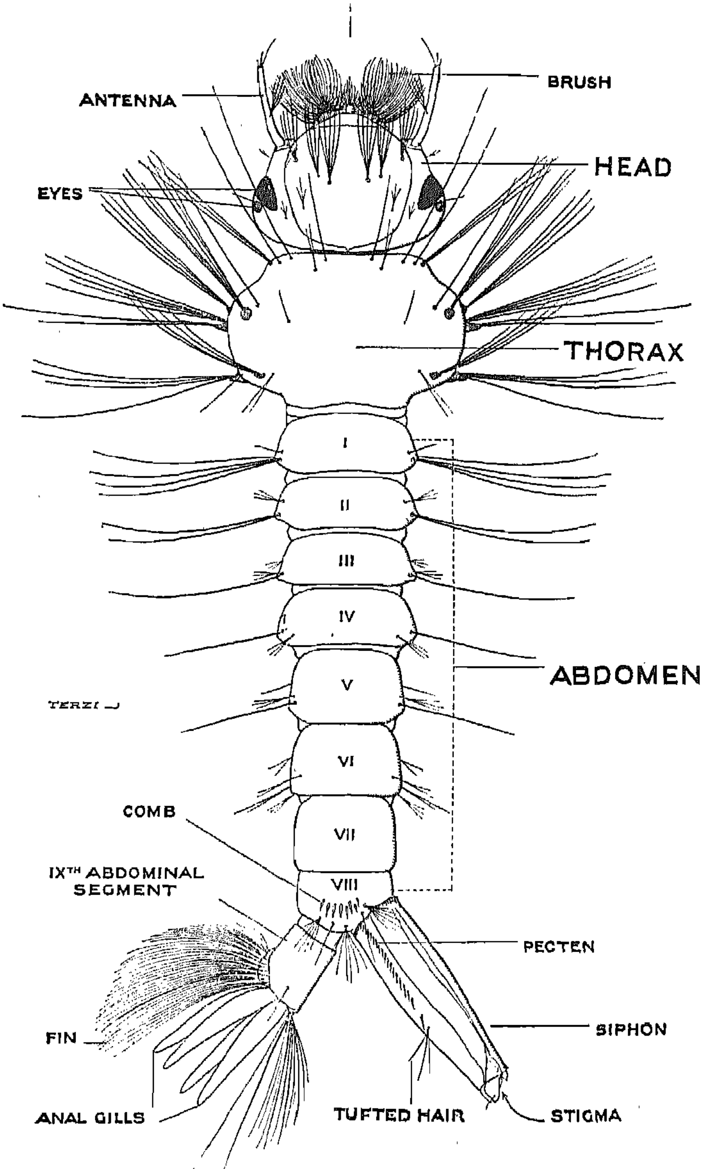


FIG. 15.—LARVA OF A CULICINE MOSQUITO: DORSAL VIEW

The eighth and ninth abdominal segments are twisted round so as to present a lateral view to show the siphon, comb and fin. (After W. D. Lang, "A Handbook of British Mosquitoes.")

markings on mosquito eggs, which are so useful a feature in the identification of many of the species, are always due to variations in the form and structure of the enveloping membrane. If this membrane is stripped from the egg, the chorion will always be found to exhibit a shiny dark brown or black colour, and, once the enveloping membrane is removed, the egg can be easily submerged, and sinks to the bottom of the water. It is, therefore, clear that the main function of the enveloping membrane is to maintain the egg at the water surface. The waterproof qualities of the membrane. and the air-containing cells in its structure enable the forces of surface-tension easily to overbalance the weight of the egg and thus maintain it at the surface. The eggs of anophelines are usually beautiful objects when examined under the microscope, and the shapes, sizes and varying structural details afford valuable specific characters to the student. The eggs of those species of culicines, which are laid in raft formation and have a vertical disposition on the water-surface, "draw" practically no water and are also almost entirely supported by surface-tension pressure. As the whole egg-surface is "waterproof," the spaces between the separate eggs do not become water-logged by capillarity, and, moreover, at the downward or blunter end of the eggs many species have a remarkable small pneumatic structure, termed the *corolla*, shaped something like the head of a discal flower, which, by holding air between its hairlike "petals," presents an air-cushion to the surface of the water. The embryos of all species escape from the eggs by cutting through the eggshell at the blunter end of the egg with the aid of a chitinous chisel-shaped organ, termed the *egg-breaker*, which is situated on the dorsal aspect of the head. This organ can be seen in 1st instar larvæ, but is lost at the first moult.

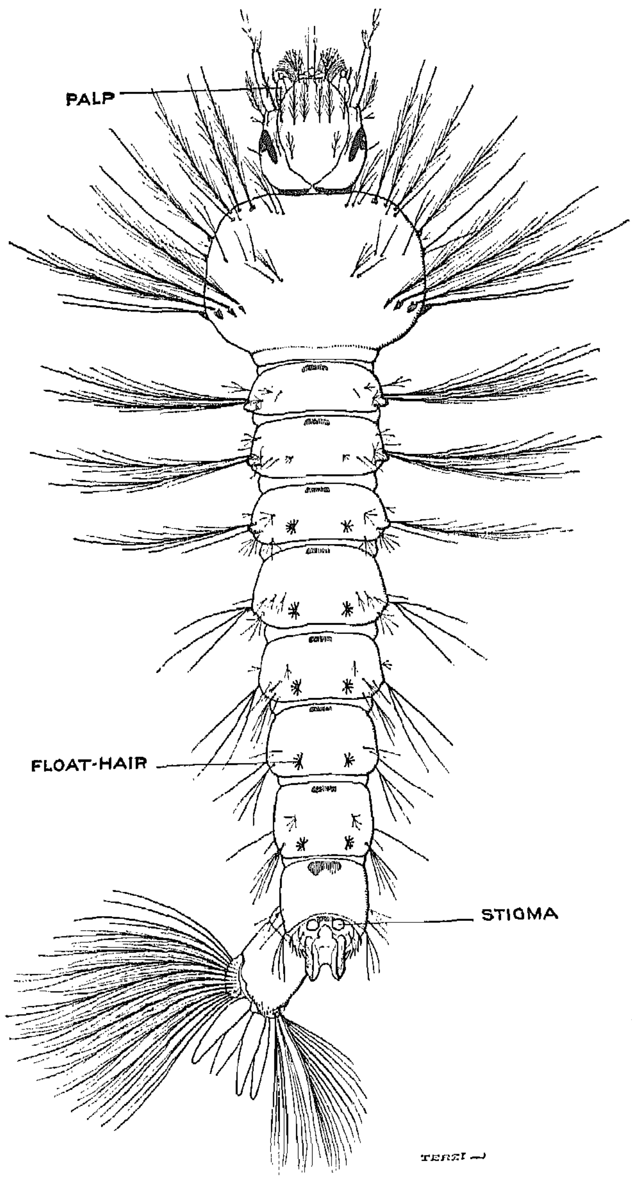


FIG. 16.—LARVA OF AN ANOPHELINE MOSQUITO: DORSAL VIEW

The ninth abdominal segment is twisted round so as to present a lateral view to show the fin. (After W. D. Lang. "A Handbook of British Mosquitoes.")

The Larva. The body of the mosquito larva may be divided conveniently into five distinct parts. The *head*, the *thorax*, the main portion of the *abdomen*, the *siphon* or *siphonal-plate*, and the *anal segment* (the two latter parts being sub-divisions of the abdomen). (*See Fig.* 15, *page* 70, *and Fig.* 16, *page* 72). The shape of the head may be said to be a dorso-ventrally flattened oval. On each side

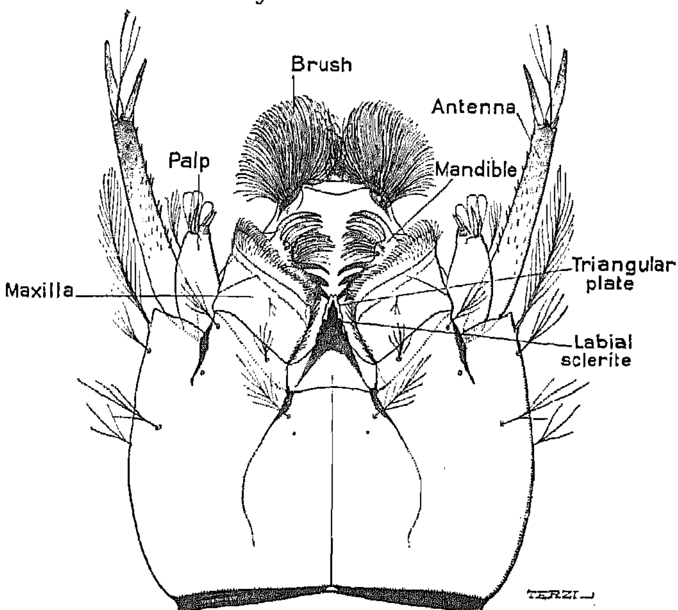


FIG. 17.—VENTRAL VIEW OF THE HEAD OF AN ANOPHELES LARVA TO SHOW MOUTH-PARTS.
(After W. D. Lang. "A Handbook of British Mosquitoes")

of the head there is a short antenna, situated ventrally are the complex mouth-parts, and at various situations on the head there are the numerous groups of ornamental hairs which are so useful in identifying the species. Further, it should be noted that in many species the antennæ of the larvæ take the form of either a smooth-surface shaft, or a spiculed-shaft, *i.e.*, a shaft on which there are numerous small spines or *spicules*.

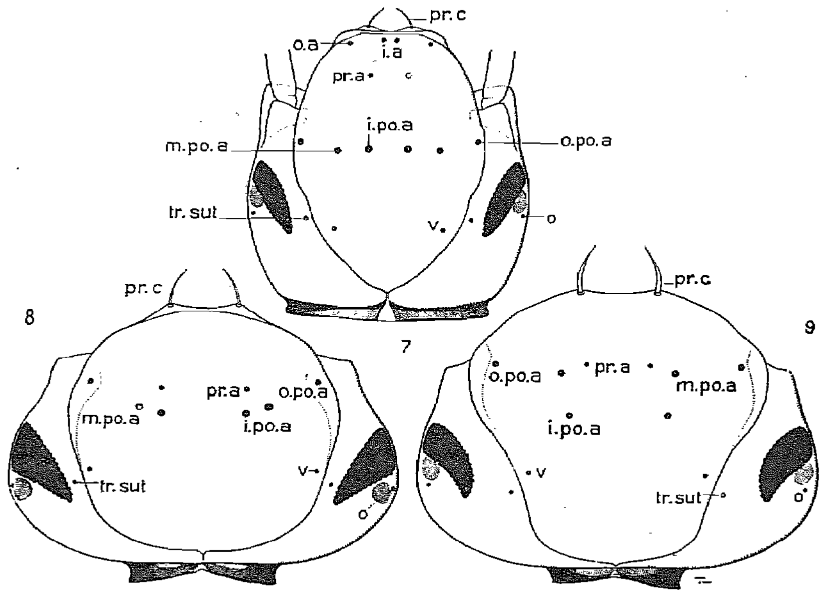


FIG. 18.—HEADS OF ANOPHELINE AND CULICINE LARVÆ TO SHOW DISTRIBUTION OF HAIRS

7, *Anopheles* larva; 8, *Theobaldia* larva: 9, *Ochlerotatus* larva.

(After W. D. Lang, "A Handbook of British Mosquitoes")

The mouth-parts (*Fig.* 17, *page* 73) consist essentially of the buccal cavity below which is a triangular plate with serrated free edges, called the *mentum (labial sclerite),* and the buccal cavity is flanked on each side by one of a pair of *palpi,* a pair of *maxillæ,* a pair of *mandibles* and a pair of *mouth-brushes.* The form of the mentum differs considerably among the different larvæ, and is a character of some diagnostic importance. The function of the mouth-brushes is to set up a current in the water by which floating particles are brought to the mandibles and maxillæ to be crushed and chewed by the former, while the latter forms the chewed mass into a bolus that is ultimately swallowed. Unpalatable floating particles are rejected. The mouth-brushes are at times incidentally used as swimming organs, the larva gliding through the water with the abdominal muscles at rest, locomotion being accomplished by the tractor action of the beating mouth-brushes.

On the dorsal surface of the head of mosquito larvæ there are important groups of hairs whose number, relative position and structure afford specific characters. The dorsal surface of the head is formed by a chitinous plate called the *clypeus*, which, anteriorly, occupies the whole width of the head, but farther back is flanked on each side by lateral chitinous plates carrying the antennæ and eyes. These hairs are therefore termed the *clypeal hairs*, and typically they may be placed in four rows. The first row occurs on the anterior edge of the clypeus and consists of two pairs of hairs—the *inner anterior* and *outer anterior* pairs (*Fig.* 18, i.a. *and* o.a., *page* 74). They are always present in the larvæ of the anopheline mosquitoes, but are usually lacking in culicine larvæ. On the extreme anterior edge of the clypeus, or situated on two protuberances in front of the clypeus, in both anopheline and culicine larvæ, are two short

forwardedly directed spines known as the *pre-clypeal* spines (*Fig.* 18, pr. c., *page* 74). The second row of clypeal hairs consists of a single pair, termed the *pre-antennal* hairs. In anopheline larvæ these hairs are situated in front of the antennæ, one on each side of the median line of the head. In culicine larvæ the pre-antennal hairs are often reduced to small inconspicuous hairs with different situations among the separate species (*Fig.* 18, pr. a. *page* 74). The third row of clypeal hairs is composed of the *inner, mid* and *outer post-antennal* hairs arranged in a posteriorly-curved line just behind the antennæ (*Fig.* 18, i. po. a, m. po. a, o. po. a., *page* 74). The fourth row consists of a single pair of hairs, termed the *vertical hairs* (*Fig.* 18, v., *page* 74), which are small hairs situated on the clypeus opposite the inner posterior aspect of the eyes. In addition to the clypeal hairs, there is a pair of hairs on the two lateral segments of the head, the component hairs being situated one on each side of the eyes. The two hairs beyond the outer aspect of the eyes, and the two hairs within the inner aspect are respectively termed the *ocular* and *trans-sutural* pairs.

The head is attached by a short cylindrical neck to the thorax, which is generally about the same length or a little longer than the length of the head. The thorax is, however, usually broader than either the head or abdomen, especially in fully-developed larvæ. The dorsal and lateral aspects of the thorax carry numerous hairs of very variable structure among the different species, and these hairs are of considerable taxonomic importance. On the anterior dorso-lateral aspects of the thorax are two protrusible and retractile organs, one situated on each side. These organs are remarkable structures, and, on account of their transparency, are likely to be overlooked. They are fairly easily seen under the microscope in the larvæ of most anophelines,

but although, after considerable search, I have not personally seen them in culicine larvæ, I am informed by Professor A. Alcock, F.R.S., that he has encountered them in larvæ of the culicine group also. Nuttall and Shipley (1901) were the first to note the occurrence of these organs ; more recently, Iyengar (1921) in India has studied them fairly closely, and has illustrated their appearance, but their exact function is at present unknown. I am inclined to think, from their structure and from the fact that they are so well developed and constantly present in anopheline larvæ, that they serve as attachments to the surface film to support the thorax in the horizontal position assumed by anopheline larvæ.

The abdomen is segmented and is composed of 10 segments, on which there may be numerous single, double, compound or what are termed *stellate spine hairs*, i.e., single hair tufts composed of several radially arranged components. The 9th (a very short segment) and 10th segment are bent at an obtuse angle downwards from the line of the preceding segments, and, as in the siphon-bearing species, the siphon-tube projects from the dorsal surface of the 8th segment at an almost similar angle upwards ; thus the tail end of these larvæ appears to be bifurcated. In anopheline larvæ the siphon-tube is absent and consequently the bifurcated appearance is not encountered.

Mosquito larvæ may conveniently be divided into two groups : (1) the *siphon-tube* bearing larvæ, and (2) the larvæ in which a *siphonal* or *stigmal plate* is carried in place of the siphon tube. The former belong to the *Tribe Culicini* and the latter belong only to the *Tribe Anophelini*.

The functions of the usual siphon-tube and the siphonal-plate are essentially the same, *i.e.*, to carry the apertures of the two large stems of the

tracheal system to the air above the surface of the water for the gaseous exchanges in the respiration of the larvæ. Among the siphon-bearing larvæ there are a few species, however, which have modified siphons to enable the larvæ to obtain the necessary oxygen, not from the air direct, but from the oxygen in the tissues of submerged water-plants. In such larvæ the tip of the siphon-tube is equipped with a small cutting apparatus to enable an incision to be made in the plant stem, through which the tip of the siphon is inserted into the oxygen-containing vessels of the plant (*Fig.* 19, *below*).

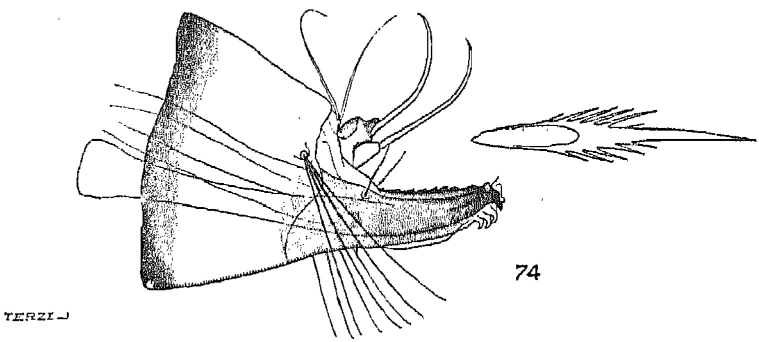


FIG. 19.—SIPHON OF *Tæniorhynchus richiardii*
(After W. D. Lang, "A Handbook of British Mosquitoes")

The morphology of the larval siphons and siphonal or stigmal plates is of great importance in the classification and identification of the species. Among the majority of the larvæ of the siphon-bearing species, along each side of the siphon-tube is a structure called the *pecten*. The pecten consists of a variable number of separate teeth, often somewhat resembling the arrangement of the teeth of a comb. The microscopic form of the teeth is simple in some species and highly complex in others, while the average number of teeth present in any particular species is fairly constant—both being matters of importance in the specific

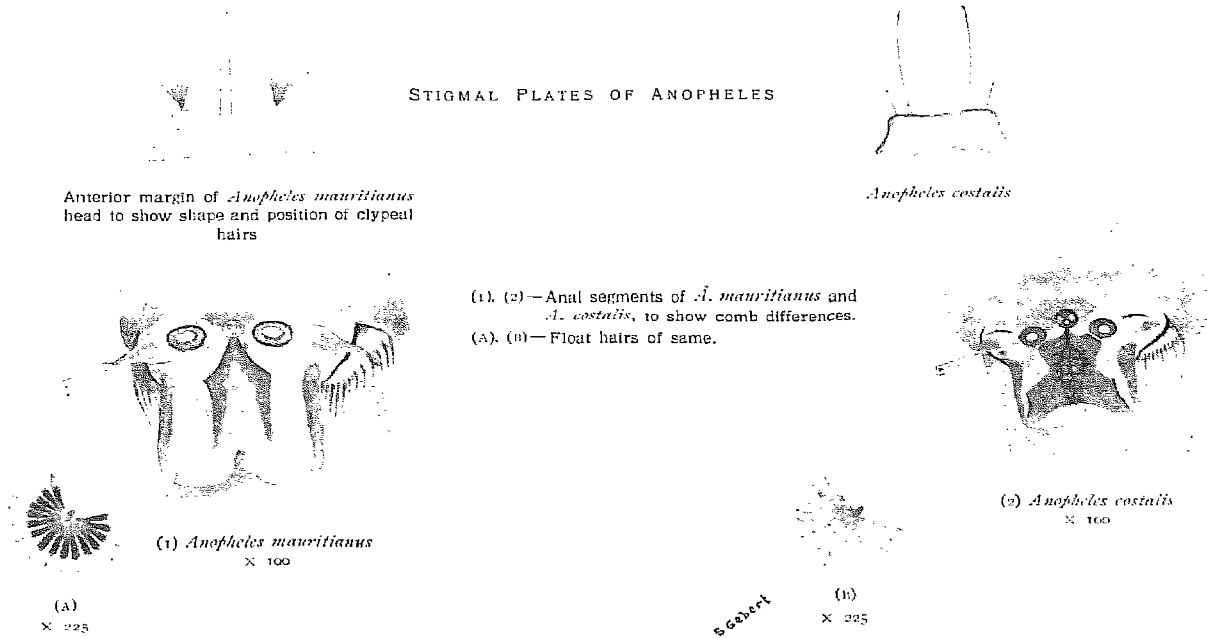
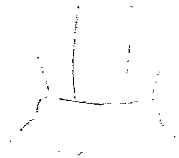


Fig. 20.—Showing the differences in the structure of the specific characters (clypeal hairs, stigmal plates, "combs" and palmate hairs) of *Anopheles mauritianus*, *Anopheles costalis*, *Anopheles maculipalpis* and *Anopheles funestus*.

[*See also over*

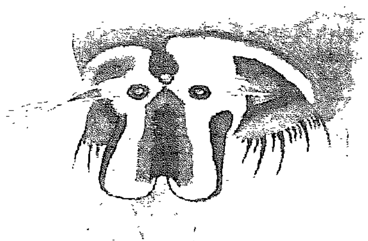
STIGMAL PLATES OF ANOPHELES



Anopheles maculipalpis

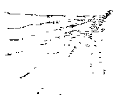
Anopheles funestus

(3), (4)—Anal segments of *A. maculipalpis* and *A. funestus*, to show comb differences.
(C), (D)—Float hairs of same.



(3) *Anopheles maculipalpis*
× 100

(4) *Anopheles funestus*
× 100



(C)
× 225

(D)
× 225

FIG. 20 *(continued)*.—Showing the differences in the structure of the specific characters (clypeal hairs, stigmal plates, "combs" and palmate hairs) of *Anopheles mauritianus*, *Anopheles costalis*, *Anopheles maculipalpis* and *Anopheles funestus*.

[*See also over*

identification of larvæ. Groups of hairs often occur at different situations on the siphon-tube, also serving as identification characters in many species, while the general shape and the ratio between the length and the breadth of the siphon are important characters for the same reason. On each side of the 8th abdominal segment in most of the siphon-bearing larvæ, near the base of the siphon, is a patch of spines whose form, number and microscopic structure frequently afford definite specific characters. This patch of spines is called the *comb*.

In anopheline larvæ the pecten is represented possibly by the large combs of teeth situated below, and one on each side of the stigmal plate. The structural characters of these combs are equally important aids to the differentiation of the larvæ of the anopheline species, while the shape of the stigmal plate and its structural details often provide characters that are quite specifically diagnostic (*Fig.* 20).

On the dorso-lateral aspects of the abdominal segments 3-5, most anopheline larvæ carry a pair of modified hairs called the *palmate hairs* (or "float" hairs) on account of their resemblance to the form of a palm-leaf. These palmate hairs serve to support the abdomen horizontally below the water-surface by breaking through the surface-film so that they are acted upon by the forces of surface-tension. The separate "leaves" of the palmate hairs of the different anopheline species widely vary in their structural details. Some species have the "leaves" serrated along their free edges, others have "leaves" which are apically terminated by a long filamentous thread; in yet other species the "leaves" are modified from the typically palmate disposition to form what more nearly resemble "tassels" or, again, the "leaves" may be fluted, etc.

On all, or some, of the abdominal segments of both anopheline and culicine larvæ, strongly chitinised plates are found in the larvæ of particular species. These plates occur on the dorsal surface of the abdomen, and they too are valuable characters in the identification of larvæ.

In all mosquito larvæ, the 10th abdominal segment, together with the preceding short 9th segment, is bent downwards at an obtuse angle from the line of the other segments. The 10th segment terminates abruptly and carries on its free edges three important structures. These are: (1) the *fin*, a cluster of long, backwardly projecting hairs situated on the ventral angle of the terminal free edge of the 10th segment; (2) two pairs of *anal gills* situated about the middle point of the terminal free edge of the 10th segment; and (3) the *anal gill hair-tufts*, situated on the dorsal angle of the terminal free edge of the 10th segment. The *anal gills* are four hyaline thin-walled sac-like organs within which there are extensive systems of tracheoles, which seems to indicate that the anal gills have a respiratory function, probably absorbing the dissolved oxygen from the water.

However, the exact function of the anal gills is not known, and since the form of both pairs of gills, in some species, is similar, and in other species the form of one pair differs from the form of the other pair, it is probable that the function of the anal gills is not solely respiratory.

Moreover, in the majority of species the anal gills are sausage-shaped, with the free end of each gill somewhat, or distinctly, pointed; but in many species that live in waters of high densities—such as the waters of salt-marshes and the waters of tree-holes—the anal gills are often greatly reduced in size and are of a round or ovoid form. The anus opens between the bases of the anal gills.

In some mosquito larvæ which have predatory habits and live by capturing and consuming other mosquito larvæ, etc., the hairs of the mouth-brushes are cemented together to form a pair of fangs for seizing and gripping the prey while the body of the unfortunate victim is slowly chewed by the mandibles until gradually the whole body, with the exception of the head, tail and siphon, is swallowed.

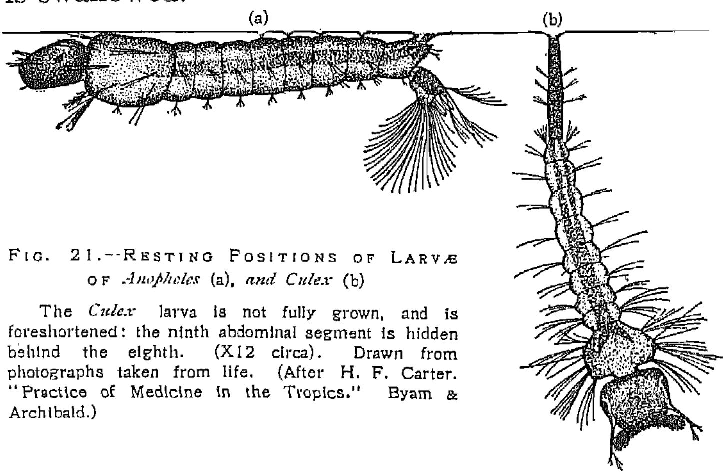


FIG. 21.—RESTING POSITIONS OF LARVÆ OF *Anopheles* (a), *and Culex* (b)

The *Culex* larva is not fully grown, and is foreshortened: the ninth abdominal segment is hidden behind the eighth. (X12 circa). Drawn from photographs taken from life. (After H. F. Carter. "Practice of Medicine in the Tropics." Byam & Archibald.)

The larvæ of the air-breathing species attach themselves to the surface film by means of the apex of the siphon or by the siphonal or stigmal plate in the case of the anophelines. The bodies of the species, having a distinct siphon, hang below the water at an angle to the surface, and, while feeding, the head is in the normal position. The bodies of the anophelines, however, since they are not equipped with a projecting siphon, lie at the surface with the stigmal plate exposed to the air, and consequently lie almost parallel to the surface of the water (*see Fig.* 21, *above*). Moreover, note particularly, that when feeding, anopheline larvæ rotate their heads through an angle of 180°, thus bringing the ventral surface of the head uppermost

and into the same plane as the back of the animal. This is because anopheline larvæ feed almost entirely upon the minute organisms and particles of organic matter that are in contact with the surface film. When anopheline larvæ either swim or dive, the head is turned back with the mouth-parts downwards.

The Food of Mosquito Larvæ (excluding, of course, the predaceous larvæ) consists of a varied diet, and while at times they consume small vegetable and animal organisms, such as algæ, bacteria and protozoa, their main diet undoubtedly consists of decomposing organic material derived from the plants of the breeding-place. Most mosquito larvæ, in the absence of sufficient other food, will feed on the dead bodies of their companions, or they may resort to cannibalism. Some will even complete their development most successfully on a wholely artificial food supply, if they are fed on boiled potato or hard-boiled egg-yolk, for instance.

The Internal Anatomy of mosquito larvæ is simple.

Respiration in culicine larvæ is mainly conducted from the two apertures at the apex of the siphon, or from the two openings *(stigmata)* on the stigmal plate in the case of anophelines. These apertures are the open ends of the two main tracheal stems which run the whole length of the abdomen and thorax on each side of the middle line. The two main tracheal stems are united at their anterior ends by *commissures* or separate connecting links, and dilate, just before these anterior links, into two large air-chambers. Along the whole length of the main tracheal stems other smaller tracheæ are given off, and by repeated sub-divisions of these subsidiary tracheæ they are finally divided

into an immense net-work of tracheoles which carry air to every organ and cell in the body. The air is renewed in the tracheoles and the carbon dioxide and other gases are exhaled by the compression and dilatation of the tracheal system caused by the muscular contractions of the animal, and also, chiefly, by the regular peristaltic pulsations which occur in the two main tracheæ. These pulsations of the tracheæ are augmented by the expansion and contraction of the heart, which lies below and between the main tracheæ.

The Alimentary System of the larvæ is similar in its principal characters to that of the adults. However, the sac-like œsophageal diverticula (food-reservoirs) of the adult are not present in the larvæ, and in the latter the crop (œsophageal valve) is relatively a very much larger structure surrounded by from 6-8 short diverticula whose walls are composed of large spherical cells. The salivary glands of the larvæ are a pair of simple tubular glands situated just within the anterior portion of the thorax. In the larvæ only rudimentary structures represent the reproductive organs. It is important to note, however, in the case of many species, that these rudimentary reproductive organs enable a determination of the sex of the developing mosquito to be made. (Adie, 1912; Langeron, 1926.) In male larvæ, two roughly oval, frequently dark brown or blackish, sacs may be seen to lie within and on each side of the 6th abdominal segment; or to extend within the 6th segment partially into either the 5th or 7th segments. These sacs are the rudimentary testes, and larvæ which exhibit these structures will be found to give rise to male mosquitoes. In some species the rudimentary testes are somewhat difficult to observe, owing to the fact that they are semi-transparent and are

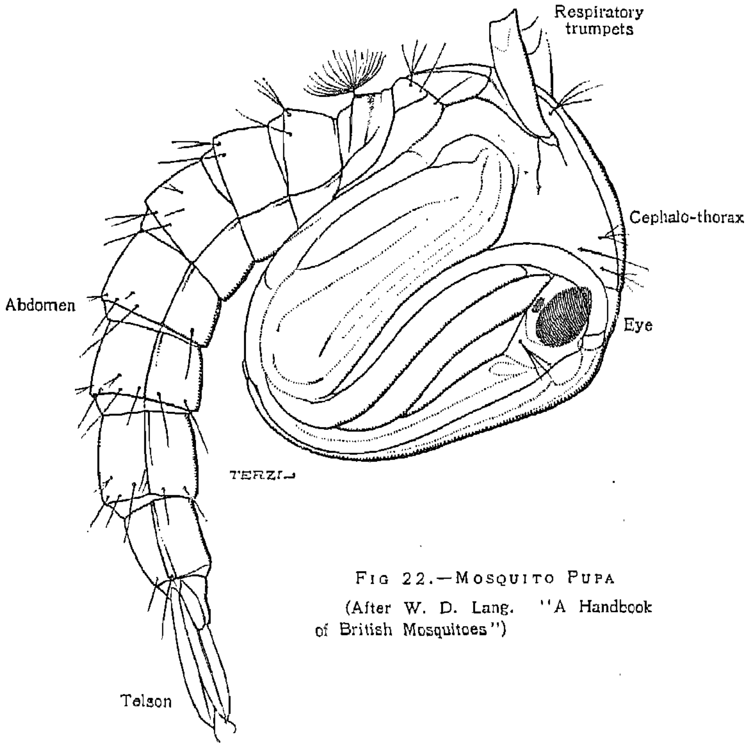


FIG 22.—MOSQUITO PUPA

(After W. D. Lang. "A Handbook of British Mosquitoes")

thus not easily differentiated from the other internal organs; but nevertheless, it is generally possible in this way to determine the sex of the larva if it is examined under a binocular microscope with obliquely transmitted illumination. Mosquito larvæ are well provided with the fat-storage tissue called the fat-body. It occurs in large masses in the thorax and in all the segments of the abdomen, becoming most conspicuously developed in the 4th instar larvæ just before pupation. The fat-body of many species of mosquito larvæ is prone to infection with several species of the sporozoa, particularly with those of the Genus *Thelohania*, which cause an infectious and fatal disease among the larvæ. Mosquito larvæ are also subject to fatal diseases of bacterial and fungoid origin.

The Pupa. (*Fig.* 22, *page* 84.) The shape of the pupa differs entirely from that of the larva. The pupa has aptly been described as "comma-like." The "tail" of the comma consists of the abdominal segments, the terminal segment bearing paddle-shaped structures termed the *telson*. The head of the comma is composed of an enlargement of the puparium which contains the head and thorax of the developing adult mosquito, and is consequently termed the *cephalo-thorax*. On each side of the cephalothorax are tubular or trumpet-like organs called the *breathing trumpets*, which, in a similar manner to the siphons, are thrust through the surface film of the water and open to the air above. The form of the breathing trumpets among the different species varies considerably, and in some cases affords specific identification characters. In the respiration of the pupa the air collected by the breathing trumpets enters the body of the mosquito through the thoracic stigmata situated on the anterior lateral aspects of the insect's thorax. The general characters of all mosquito pupæ

are so closely alike that it is rarely possible to identify the species from their respective pupæ. Occasionally, in certain species, fairly definite generic and specific characters are met with, and these, when they occur, take the form of special hair-tufts on each side of the posterior end of the abdomen near the telson; keel-like projections on the thorax; differences in the shape of the air-trumpets; and in the respective sizes of the different species of the pupæ. The sex of the pupæ of many species may be determined by the presence or absence of the rudimentary testes (*see foregoing section, page* 83). In the pupæ the testes occur within the 6th abdominal segment, and extend into the 5th segment, and lie, moreover, one on each side of the median line of the abdomen instead of being placed laterally.

PART II

THE MOSQUITOES OF MAURITIUS AND RODRIGUEZ

WITH the object of meeting the needs of both untrained and trained anti-malaria workers, Part I has been devoted to a brief account of the anatomy and bionomics of mosquitoes in general, while Part II is devoted to the scientific study of the characters and bionomics of the particular local species. In the course of time it is not improbable that other species and even genera may be encountered in Mauritius and Rodriguez. Workers in these two Islands should also, therefore, study Mr. F. W. Edwards' latest list of the genera of the Tribe *Culicini*, which is included at the end of this division. Thus, should future workers encounter mosquitoes not belonging to the genera now recorded from Mauritius and Rodriguez, it will be possible for them to refer the new discovery to its correct genus; and, by dispatching specimens to any of the recognised systematic authorities, to have the specimens correctly identified.

In this connection it will be well to remind the reader that when he discovers what he considers is a new mosquito, the larvæ of this species should, if possible, be obtained. At the laboratory, about a dozen of these larvæ should be placed in the water of the natural breeding-place, under conditions of temperature and lighting comparable

to those of the natural breeding-place, and the larvæ should be allowed to complete their development under close observation.

The mosquitoes which emerge from these larvæ must then be carefully compared with the previously captured specimen, so as to ensure the relationship of the larvæ and the adults, and when this relationship is definitely established, further specimens of these larvæ should be preserved (*see page* 203) so that they may accompany the mosquitoes sent for identification.

Remember, when sending mosquitoes for this purpose, that specimens of both *males and females* of the same species are always required.

General Classification of the Mosquitoes

(*continued—see page* 31)

We have now to return to the subject of the classification of the mosquitoes from the point at which this subject was left in Part I, *page* 31.

Edwards divides the Sub-Family *Culicinæ* into two *Tribes*: 1. The *Anophelini*; 2. the *Culicini*. Within the Tribe *Anophelini* there are one *Genus*, five *Sub-Genera* and a large number of *Species*. The recorded anopheline species number between 130-140.

Within the Tribe *Culicini* there are thirty-one *Genera*, an equal or larger number of *Sub-Genera*, and a very large number of *Species* and varieties of these species. The recorded culicine species number between 1500-2000.

The main divisions of the general system of classification of the Sub-Family *Culicinæ* will be clear after a little study of the list of genera and species on *pages* 90, 98, 99 *and* 184-188, and the following graphical arrangement:—

CULICIDÆ

Tribe *ANOPHELINI*	Tribe *CULICINI*
Genera	Genera
Sub-Genera	Sub-Genera
Species	Species
Varieties	Varieties

It should be remembered that all systems of classification are to a great extent arbitrary systems. Natural evolution is constantly branching out along different routes. The route-map of the process an æon ago may be totally dissimilar to that of the progress made an æon hence. The best that we can do for our own systems of classification is to arrange the insects on the basis of their obvious or apparent relationships. Naturally, in so arbitrary a system, there are differences of opinion as to these relationships, but, fortunately, there is at last a fairly satisfactory international agreement on the subject.

Lists of Local Species. Up to the present, careful revision of the records and actual specimens has shown that there are 17 definitely identified and 2 unidentified species recorded from Mauritius. The two latter are represented, in one case, by a badly-damaged adult of the Genus *Tæniorhynchus*, and in the other case by larvæ of the Genus *Culex*, which were discovered in a tree-hole at Reduit. The number and distribution of the siphon hair-tufts, and the apparent absence of combs on the lateral aspects of the 8th abdominal segment, would appear to distinguish these larvæ from the larvæ of the other local *Culex* species, but, un-

The Genera, Sub-Genera and Species Known to Occur in Mauritius

Tribe	Genus	Sub-Genus	Species found in Mauritius
Anophelini	*Anopheles*	*Anopheles*	*A.* (*M.*) *funestus*, Giles
			A. (*A.*) *mauritianus*, Grandpré
		Myzomyia	*A.* (*M.*) *costalis*, Loew
			A. (*A.*) *maculipalpis*, Giles
Culicini	*Aëdes*	*Stegomyia*	*A.* (*S.*) *argenteus*, Poiret
			A. (*S.*) *albopictus*, Skuse
			A. (*S.*) *mascarensis*, MacGregor
		Aëdimorphus	*A.* (*A.*) *nigerensis*, Theobald
	Orthopodomyia		*Orthopodomyia arboricollis*, d'Emmerez de Charmoy
	Tæniorhynchus	*Tæniorhynchus*	*Tæniorhynchus* (sp. incerta)
	Lutzia		*Lutzia tigripes*, Grandpré and de Charmoy
	Culex	*Culex*	*Culex rima*, Theobald
			Culex univittatus, Theobald
			Culex fatigans, Wiedemann
			Culex pipiens, Linnæus
			Culex quasigelidus, Theobald
			Culex tritæniorhynchus, Giles
			Culex (sp. incerta)
			Culex thalassius, Theobald

The Genera, Sub-Genera and Species Known to Occur in Rodriguez

Tribe	Genus	Sub-Genus	Species found in Rodriguez
Culicini	*Aëdes*	*Stegomyia*	*A.* (*S.*) *argenteus*, Poiret
	Culex	*Culex*	*Culex fatigans*, Wiedemann
			Culex simpsoni, Theobald

fortunately, the larvæ died before their development had been completed, and the identification of the species has therefore not yet been possible. The identified and unidentified species from Mauritius represent five genera and 19 species.

From Rodriguez, only three species representing two genera have been collected.

The Tribes

As will be observed from the foregoing lists, mosquitoes of both the Tribal divisions of the *Culicinæ* (i.e., *Anophelini* and *Culicini*) occur in Mauritius. In Rodriguez, on the other hand, only mosquitoes of the Tribe *Culicini* have been found.

Tribal Characters

ADULTS

1. Mosquitoes having the palpi of both sexes as long as the proboscis. Terminal joints of the male palpi often thickened. Apical joint

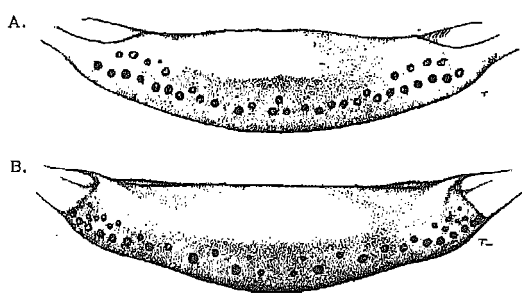


FIG. 23A.—SCUTELLUM OF *Anopheles bifurcatus*
B.—SCUTELLUM OF *Anopheles plumbeus*
(After W. D. Lang. "A Handbook of British Mosquitoes."

bluntly terminated. Thorax elongate and cylindrical; rarely rounded. Posterior (free) edge of the scutellum evenly rounded. (*Fig.* 23, *above.*) Abdomen not densely invested with flat overlapping scales ...... *Anophelini.*

2. Mosquitoes having the palpi of the females shorter than the proboscis. Palpi of the males

usually as long or much longer than the proboscis; rarely shorter than the proboscis. Terminal joints of the palpi often upturned and clad with long hairs. Apical joint usually tapering and pointed. Thorax rounded. Posterior (free) edge of the scutellum trilobate,

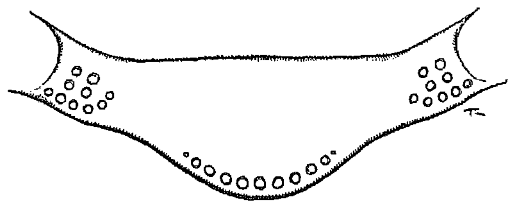


FIG. 24.—SCUTELLUM OF CULICINE MOSQUITO TO SHOW TRILOBATE CONDITION
(After W. D. Lang. "A Handbook of British Mosquitoes")

the central lobe always distinct. (*Fig.* 24, *above.*)

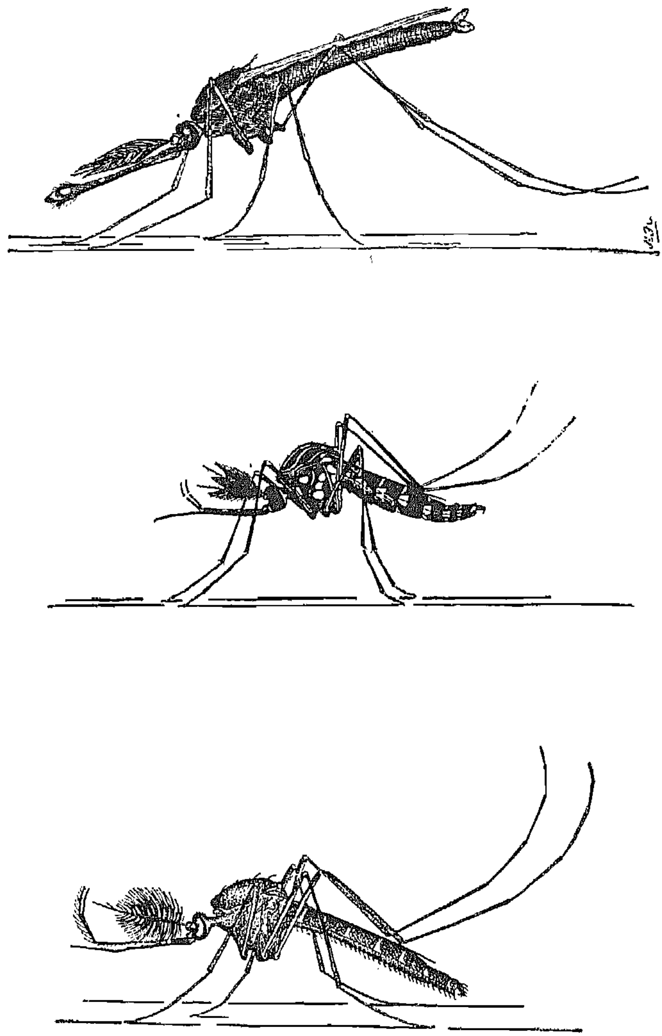
Abdomen densely invested with flat overlapping scales .... *Culicini.*

LARVÆ

1. Larvæ without an air-siphon, but with a conspicuous stigmal plate. Palmate hairs (or modifications of such hairs) usually present on the dorsal surface of the abdominal segments 3-7. Bodies of the larvæ, when at rest or feeding, lie parallel to, and in contact with, the surface film. When feeding at the surface, the head is rotated through an angle of 180° so that the mouth-parts are then in a dorsal position (*Fig.* 16, *page* 72) *Anophelini.*

2. Larvæ with a distinct air-siphon. No palmate hairs on the dorsal surface of the abdominal segments. Bodies of the larvæ, when at rest at the surface of the water, hang at an angle below the surface-film. Head is not rotated when feeding (*Fig.* 15, *page* 70) ...... *Culicini.*

The Tribe Anophelini. Since many of the species of the *Anophelini* are the vectors of malaria, this tribe is perhaps the most important from the aspect of public health. The most conspicuous characters which distinguish the *Anophelini* from the other tribes are that the free posterior margin of the scutellum is evenly rounded (*Fig.* 23A *and* B, *page* 91) and that the thorax is elongate and roughly cylindrical, in contrast to the trilobate scutellum and the spherical shape of the thorax in the *Culicini*. The palpi are composed of four segments and are about as long as the proboscis in both sexes. In the males the two terminal joints of the palpi are usually swollen and are decorated with hairs, while in the female the palpi are of almost uniform width throughout their length. Speaking generally, it may be said that the thorax and abdomen of the *Anophelini* are not clothed with such a complete vestiture of scales as is the case among the *Culicini*. The proboscis, palpi, legs and wings are, however, almost always densely clothed with scales. The legs of the *Anophelini* are very long and slender, and the tarsi of the hind pair of legs are longer than the tibiæ. When standing at rest on any surface, most of the members of the *Anophelini* adopt the characteristic posture of standing with the head pointing downwards towards the surface on which they are resting, while the abdomen points upwards. In this way the bodies of most of the *Anophelini* are inclined at a sharp angle to the surface, whereas the bodies of the members of the *Culicini* are usually supported at rest almost parallel to the surface on which they are standing. (*Fig.* 25, *page* 94.) It is well to point out, nevertheless, that this is not an infallible characteristic, as one or two species of anopheles (*Anopheles culicifacies*, for example —an Indian species) stands with its body parallel to the surface, and, under certain conditions, some species of the *Culicini* assume an angular posture.



(a)

(b)

(c)

Fig. 25.—RESTING POSITIONS OF MOSQUITO

Resting positions of (a) *Anopheles maculipennis*, Mg.; (b) *Aëdes (Stegomyia) argenteus*, Poiret; (c) *Culex pipiens*, L. (× 6 circa). Drawn from photographs taken from life by Prof. R. Newstead and H. F. Carter. (After H. F. Carter: "The Practice of Medicine in the Tropics." Byam & Archibald.)

The best single diagnostic *Anopheline* character is the form of the palpi in the two sexes—the long palpi of the females and the long apically swollen palpi of the males.

The wings of most species of *Anophelini* are densely clothed with scales. These are often a mixture of black and white or black and yellow scales, and frequently give to the wings a specifically figured or spotted pattern. The old popular idea "that anophelines have spotted wings" is, nevertheless, a totally unreliable characteristic by which to distinguish anopheline mosquitoes, for while it is true that most *Anopheles* have spotted wings, there are several species which have uniformly coloured wings without a figured pattern, and there are, moreover, several species of culicine mosquitoes with elaborately patterned wings.

The larvæ of the *Anophelini* are devoid of siphon-tubes, and are equipped instead with a stigmal plate situated on the dorsum of the 8th abdominal segment, on which the branches of the two main tracheæ open to the air. The shape and structural details of the stigmal plate afford valuable specific identification characters. Anopheline larvæ feed mainly on organic particles floating on the surface-film, which they consume by rotating their heads through an angle of 180°, thus bringing the mouth into contact with the surface-film and into the same plane as the back of the animal. Consequently, anopheline larvæ, when resting at the surface or feeding, lie with their bodies in a horizontal position, and they only descend to hide when escaping danger. In this we have an infallible anopheline larval character, and although some species of culicine larvæ, which are provided with very short siphon-tubes, also rest almost parallel to the water-surface, they invariably do not rotate their heads when feeding.

There are no conspicuous or definite characters which will with certainty differentiate the pupæ of the *Anophelini* from those of the *Culicini*. Pupæ must be kept under suitable conditions so that the mosquitoes which emerge may be identified.

KEY FOR THE IDENTIFICATION OF THE KNOWN GENERA OF THE MAURITIAN MOSQUITOES

(Based on Edwards' classification)

ADULTS

1. Thorax cylindrical; free edge of the scutellum evenly rounded, female palpi as long as the proboscis; terminal joints of the male palpi thickened; abdomen of both sexes without a complete scale vestiture.
Anopheles (in the generic sense).

2. Thorax not cylindrical; roughly spherical. Free edge of the scutellum trilobate; female palpi not as long as the proboscis; male palpi usually longer than the proboscis; abdomen of both sexes with a complete scale vestiture...... 3

3. Pulvilli (*Fig.* 34, *page* 148) present. Mauritian species of a light to dark brown colour; not highly ornamented. Most species without markings that are conspicuously noticeable to the unaided eye, but when markings do occur, these take the form either of patches of paler coloured scales on the thorax, small patches of white scales on the palpi, or a band of yellowish-white scales on the proboscis, and the legs may have distinct pale markings. (The bands on the abdominal segments are not considered as noticeable ornamentation.) 8
Pulvilli absent. All the Mauritian species are highly ornamented insects 4

4. Two pro-epimeral bristles (*see Fig.* 6, *page* 38) present. Mauritian species (a single species), large highly decorated mosquitoes. Ground colour of the body, brownish-black; legs with broad yellow bands; wings spotted like those of an anopheline; female palpi nearly half as long as the proboscis. Length of the 1st metatarsi of the fore legs greater than that of the remaining four taken together. 4th metatarsi much shorter than the 5th, and scarcely longer than its breadth. 1st metatarsi of the hind pair of legs, and the fork-cells (*page* 45) of the wings unusually long ...... *Orthopodomyia*.
Several (about five) pro-epimeral bristles present 5

5. No post-spiracular bristles (*see Fig.* 6, *page* 38) present; female claws simple; scales of the wings unusually broad. *Tæniorhynchus.*
At least a few post-spiracular bristles present; female claws nearly always toothed 6
6. Mauritian species highly decorated 7
Mauritian species not highly decorated 8
7. Proboscis rather slender; straight or curved upwards in repose. Palpi of the female less than one quarter the length of the proboscis. In the Mauritian species the general body-colour is dark, and the legs, and often the thorax and the abdomen, are strikingly decorated with lines or patches of white scales .... *Aëdes.*
8. Lower mesepimeral bristles (*Fig* 6, *page* 38) numerous. The single Mauritian species is a large dark brown coloured insect; a sylvan species. Legs finely stippled with brilliant white dots when examined under a lens. *Lutzia.*
Normally one lower mesepimeral bristle present; often none, but very rarely two or three. Mauritian species brown; mainly without very conspicuous markings. *Culex.*

LARVÆ

1. Larvæ without a siphon. When feeding at the surface, the body lies parallel to the water-surface and the head is backwardly rotated. *Anopheles* (in the generic sense).
Larvæ with a siphon. When at the surface, the body of the larva hangs at an angle from the water-surface. In feeding, the head is not backwardly rotated 2
2. Siphon adapted for the collection of air at the water-surface 3
Structure of the siphon highly modified for sub-aquatic respiration, and provided with saw-like apparatus for the incision of vegetable tissue from which the oxygen used in respiration is obtained. (*See Fig.* 19, *page* 78.) *Tæniorhynchus.*
3. Siphon short and broad; anal segment pointed. Mouth-parts modified for predacity. Body of the larva, when at rest at the surface, hangs downwards at only a slight angle .... *Lutzia.*
Body of the larva, when at rest at the surface, hangs downwards at a distinct angle. Mouth-parts not modified for predacity. Anal segment not pointed 4
4. Pecten on siphon absent. Larvæ with extremely long hairs on thorax and abdomen, and with elaborate

hair-tufts on the head. Large chitinous plates often present in 4th instar larvæ on abdominal segments 6-8 A tree-hole species .... *Orthopodomyia.*

Pecten present 5

5. Siphon short and stout, at most four times as long as its breadth at the base. Only a single pair of ventral hair-tufts on the siphon, situated at, or about, the middle. Antennal hair-tufts generally at, or before, the middle .... *Aëdes.*

Siphon fairly long, sometimes very long and slender. Siphonal hair-tufts numerous. Antennæ with well-developed hair-tuft situated usually well beyond the middle of the antennal shaft. Two long pre-apical hairs .... *Culex.*

The Generic and Sub-Generic Divisions of the Tribe Anophelini

The *Anophelini* are divided by Christophers (*Ind. Journ. Med. Res.* iii, *page* 383, 1915) and by Edwards, who accepts this classification, into a single Genus, *Anopheles*, and five Sub-Genera, *Anopheles*, *Myzomyia*, *Nyssorhynchus*, *Chagasia* and *Bironella.* Mosquitoes of the first two Sub-Genera (*Anopheles* and *Myzomyia*) occur in Mauritius.

Sub-Generic Characters of the Tribe Anophelini

ADULTS

Found in Mauritius

Cross-veins and bases of the forks of the wing-veins with dark scales. Costa largely dark (in Palaeartic species), with at most two pale spots, apart from a pale area in the apical fringe. Male hypopygium with two (rarely three) strong spines at the bases of the side-pieces, one or both of which are borne on a strong tubercle. Prosternal (*Fig.* 6, *page* 38) hairs usually numerous ...... *Anopheles.*
(All regions of the New and Old World)

Cross-veins and bases of forks of wing-veins with light scales (except in *A. rhodesiensis*). Costa with four or more pale spots. Male hypopygium with a group of several (4-6) stiff bristles at the base of each side-piece, none of which are borne on tubercles or otherwise differentiated. Prosternal hairs nearly always reduced. *Myzomyia.*

(Mediterranean, Ethiopian, Oriental and Australian regions.)

Parabasal spines of male hypopygium, one in number, with two strong spines rising some distance up the side-piece. Wings spotted more or less as in *Myzomyia*. ...... *Nyssorhynchus*.

(Neo-tropical Region)

Side-piece of the male hypopygium with a basal lobe. Wings unspotted .... *Chagasia*.

(South America)

Side-piece of the male hypopygium without a basal lobe, but with a massive spur rising from the parabasal area; no parabasal spines. Wings unspotted; anterior fork-cell of wing very short, one-sixth of its petiole ...... *Bironella*.

(New Guinea)

LARVÆ

Found in Mauritius

Shaft of the antenna with a branched hair (except in *A. plumbeus*). Palmate hairs lanceolate, without long terminal filament. Internal clypeal hairs generally close together .... *Anopheles*.

Shaft of the antenna without a branched hair. Leaflets of the palmate hairs generally with long terminal filament. Internal clypeal hairs rather wide apart ...... *Myzomyia*.

Shaft of the antenna with a branched hair; leaflets of the palmate hairs fusiform .... *Nyssorhynchus*.

Larva with hair on the inner aspect of the antenna; leaflets of the palmate hairs racquet-shaped, with hair-like filament; respiratory apparatus with a long flagellum rising from anterior pad .... *Chagasia*.

Shaft of the antenna with a branched hair; leaflets of the palmate hairs fusiform .... *Bironella*.

THE ANOPHELINE MOSQUITOES OF MAURITIUS

Four species of *Anopheles* have been found in Mauritius, namely, *Anopheles (Myzomyia) costalis*, Loew.; *Anopheles (Anopheles) mauritianus*, Grandpré and de Charmoy; *Anopheles (Anopheles) maculipalpis*, Giles; and the recently discovered fourth species, *Anopheles (Myzomyia) funestus*, Giles. No Anophelines have been found in Rodriguez.

KEYS FOR THE IDENTIFICATION OF THE MAURITIAN SPECIES OF ANOPHELES

(ADULTS)

1. Large black or blackish-brown species; costa uniformly dark 4

2. Large black species ; costa with distinct black and white interruptions 5

3. Smaller brown species ; costa distinctly broken into dark and pale sections 6

4. Legs black or brownish-black, with distinct yellowish-white bands. 4th and 5th metatarsi of the hind pair of legs white or yellowish-white, 3rd metatarsus, apical two-thirds yellowish-white, basal third dark, followed by a yellowish-white ring at the articulation of the 2nd and 3rd metatarsi. Articulations of all the remaining joints of each pair of legs with yellowish-white bands. Proboscis and palpi shaggily clothed with scales. Exterior lateral aspects of the 3rd and 4th joints of the palpi with a small patch of white scales. *Anopheles (A.) mauritianus.*

5. Legs black, with, in the hind pair of legs, the whole of the 3rd, 4th and 5th metatarsal joints pure white ; the white being continued on the 2nd metatarsus to about its middle point. All the remaining joints of the legs stippled with brilliant white dots.
Anopheles (A.) maculipalpis.

6. Brown species ; average body length, 5 mm. Narrow, but, distinct, yellowish bands at the articulations of the metatarsal joints of the fore pair of legs. Fringe of the wing with pale areas at the terminations of veins 1-6.
Anopheles (M.) costalis.

7. Brown species, often dark brown or blackish ; average body length, 3 mm. No distinct yellowish or other coloured bands on the fore pair of legs. Fringe of the wings with pale areas at the terminations of veins 1-5, but at the termination of the 6th vein there is no pale area .... *Anopheles (M.) funestus.*

LARVÆ

1. Exterior clypeal hairs heavily branched ; palmate hairs large and distinct ; leaflets without a long terminal filament. Comb large, composed of long and short teeth alternating ...... *Anopheles (A.) mauritianus.*

2. Exterior clypeal hairs unbranched and simple ; palmate hairs distinct or indistinct ; combs of various forms...... 3

3. True palmate hairs present 5

4. Palmate hairs reduced to a brush or tassel-form 6

5. True palmate hairs present, but, owing to the transparency of the hairs, they have to be carefully looked for if they are to be seen; comb small, composed of fairly regular fine teeth .... *Anopheles (M.) costalis.*
True palmate hairs present; large, usually black, and distinctly seen; comb of moderate size, composed of long irregular teeth. Larva with large heavily chitinised plates on the dorsal surface of the abdominal segments.
Anopheles (M.) funestus.
6. Palmate hairs reduced to a brush or tassel-form; comb large, composed of teeth of irregular size.
Anopheles (A.) maculipalpis.

(*See Fig.* 20, *between pages* 78 *and* 79).

General Account of the Four Anopheline Species

Anopheles mauritianus, Grandpré and de Charmoy

Description and Bionomics

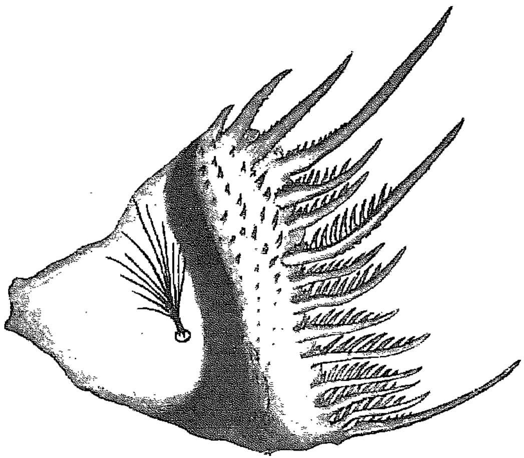
A. mauritianus is the largest species of anopheles that occurs in Mauritius. It is found in all the different districts of the Island, from sea-level to the inland mountainous regions. It breeds mainly in rural localities, preferably choosing clean natural waters, such as those of fresh-water swamps and marshes, and temporarily water-logged grassy lands. *A. mauritianus* will enter houses near its breeding-places to bite the inhabitants, and it will attack ferociously in the open during the daytime. In the laboratory captive specimens could be induced, without difficulty, to bite at any time of the day or night, but I formed the impression in the course of my work in Mauritius that this species normally shows a preference for feeding in the daylight hours. I was frequently bitten by this species in houses during the day, but never, as far as I am aware, at night—except in the case of the captive specimens who were forced to avail themselves of the only opportunity they had for getting a blood-meal.

The larvæ of *A. mauritianus* are also commonly found in vegetation-clad river-beds, in rock-holes where there is an abundance of algal growth, and in the pools, rivulets and flooded ground caused by the excessive irrigation of the sugar-cane fields. Standing, or gently flowing, water of all kinds, in rural or semi-rural localities may, in fact, be said to furnish breeding-places for this species. It does not, however, commonly breed in definitely artificial collections of water, and it is rarely found in strictly urban situations.

It has been stated that *A. mauritianus* in other parts of the world is a malaria-vector, but in Mauritius all the evidence is against the species playing any part in the transmission of malaria. Ross, in 1908, made investigations in Mauritius on the possibility of malaria transmission by *A. mauritianus,* and concluded from his findings that this species was not a vector. During 1922, I also made fairly extensive investigations on this subject, and the results of my experiments confirmed Ross' conclusions. Moreover, as there is no malaria in certain parts of the Island where, nevertheless, *A. mauritianus* abounds, the circumstantial evidence supports the conclusions arrived at experimentally.

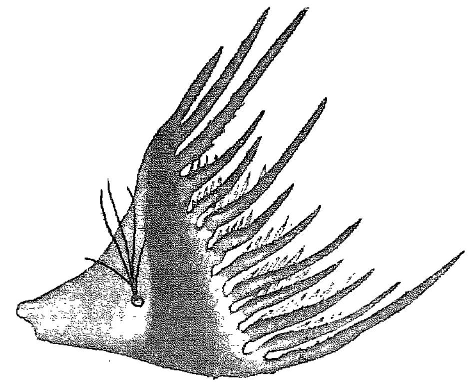
THE ADULTS. The adult insects are large dark-coloured anophelines, having the proboscis and palpi shaggily clad with scales which give the proboscis and palpi an unusually stout appearance. To the unaided eye the body and wings are black in coloration, while all the legs are conspicuously ornamented with yellowish-white bands.

In the hind pair of legs the 4th and 5th metatarsi are white or yellowish-white, as is also the apical two-thirds of the 3rd metatarsus, while the basal third of this joint is dark. All the articulations of the remaining joints of each pair of legs



Anopheles maculipalpis
× 450

S. Gebert

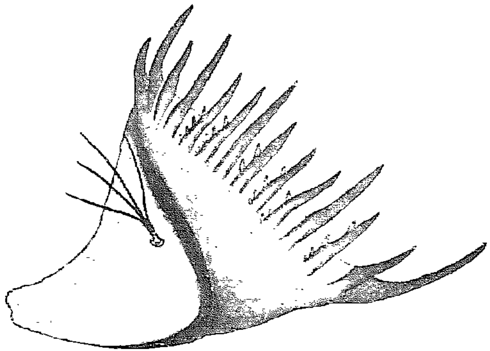


Anopheles funestus
× 450

COMBS OF ANOPHELES

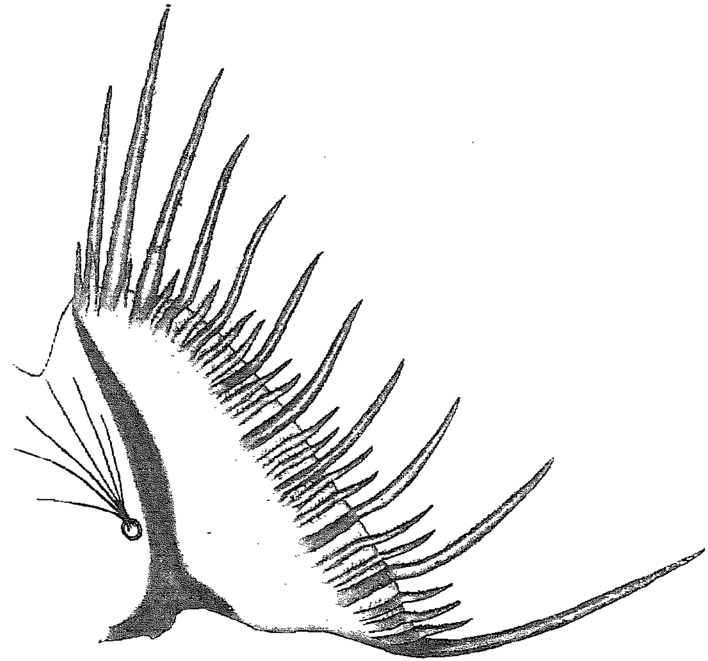
FIG. 2b.—Combs of Mauritian Anopheline larvæ

[See also over



Anopheles costalis
× 450

COMES OF ANOPHELES



Anopheles mauritianus
× 450

FIG. 26 *(continued)*.—The morphology of the "combs" of the Mauritian Anopheline larvæ

[*See also over*

are ornamented with yellowish-white bands. The costa presents a uniformly dark appearance, unbroken by alternating pale and dark areas, as is the case in the other species of anopheles found in Mauritius.

THE LARVÆ. The larvæ make no special demands in their habitats as to the presence or absence of sunlight. Usually, however, they seem to prefer partial shade. The larvæ of *A. mauritianus* are very easily identified at all instars by the presence of heavily branched exterior clypeal hairs; moreover, up to and including the 3rd instar, they present a particularly slender appearance. Neither the head nor the thorax projects conspicuously beyond the main width of the anterior part of the abdomen, while even with a hand-lens the heavily branched exterior clypeal hairs may be easily recognised. The abdominal segments carry large palmate hairs, whose separate leaflets are without a terminal filament, and the structure of the comb, with its large and short teeth alternating (*see Fig.* 26), markedly differentiates *A. mauritianus* larvæ from those of the other Mauritian species of *Anopheles*. When first it leaves the egg the minute larva is black, but even then the peculiar slenderness of the body is noticeable. At the 2nd instar the larva is still black, the slenderness of the body is more striking, and the dorsal surface of the abdominal segments are often stippled with white dots or white patches. It should be mentioned, however, that this abdominal colour-ornamentation on anopheline larvæ is not a definite specific character, since somewhat similar markings frequently occur in many species. At the 3rd and 4th instars, the larvæ of *A. mauritianus* exhibit a remarkable range of body-colour, including larvæ of a semi-transparent straw-shade, others of varying shades

of green and brown, and occasionally a few that are a deep olive-black. In the 4th instar larvæ, the thorax is considerably broader than the abdomen, and consequently, at this stage *A. mauritianus* larvæ have lost their hitherto slender appearance. However, their large size and their well-defined branched exterior clypeal hairs then clearly differentiate them from even the 4th instar larvæ of the three other Mauritian anopheline species. Unlike the other anopheline larvæ in Mauritius (but in common with some species in different parts of the world), the 4th instar larvæ of *A. mauritianus* are often marked longitudinally along the dorsal surface of the thorax and abdomen with a streak of opaque white, pinkish-white, or yellow. The significance of this very variable ornamentation, and the variation in the general body colour of the larvæ, is not obvious, since larvæ taken from the same breeding-place will often show among them individuals representing the full range of variable colours, and all degrees or the complete absence of the ornamental (?) markings.

The larvæ of *A. mauritianus*, under natural and the optimum conditions, in Mauritius, take about three weeks to develop from the egg stage to the adult insect. Under less favourable conditions in the winter months the larval stages may continue for many weeks.

THE EGGS. The eggs of *A. mauritianus* conform to the usual anopheline type, that is, they are boat-shaped, one end being broader than the other, and the enveloping membrane is developed on each side of the egg to form lateral hydrostatic floats. Longitudinally, along the median dorsal surface of the egg, the enveloping membrane leaves a line of chorion uncovered, and the edges of the enveloping membrane on each side of this uncovered line are thrown into graceful undula-

tions. Although the eggs of the Mauritian *Anophelini* were studied to some extent during my investigations, pressure of work unfortunately prevented the completion of drawings. It was ascertained, however, that the structure of the eggs of each of the species were sufficiently different to enable specific identification to be made very easily. Carefully made illustrations of the eggs of each of the four species should be undertaken by some future investigator, and would form a valuable and interesting piece of work.

Anopheles costalis, Theobald

Description and Bionomics

Anopheles costalis is exceedingly common everywhere in the coastal belt of Mauritius, where it breeds actively all the year round. It is commonly encountered up to an altitude of 1000 feet, and, under exceptional circumstances, it has been found as high as 1800 feet, at the central part of the Island near Curepipe. It demands a high temperature for its rapid development, and the variation in the atmospheric temperatures in the different districts of Mauritius has a profound influence on the development and dispersion of this species ; consequently, it is most prolific under the comparatively even high temperatures of the coastal belt. During the summer months no part of the Island may be considered safe from the invasion of at least a few *Anopheles costalis*, but the lower atmospheric temperatures of the winter months speedily kills off the vast majority of the individuals at the higher altitudes. Mainly at about 1000-1200 feet (in rare instances even higher), in certain sheltered situations, *Anopheles costalis* is able to pass the winter months often a long way from the coastal belt. These situations are always small localities where the insects happen

to find some sheltered breeding-place that is in close proximity to human dwellings or stables. Even at such sites, nevertheless, the speed of larval development is much retarded, and the species can only be said just to be maintaining itself in the face of difficulties. From these situations, which I have elsewhere referred to as the "winter-refuges" (MacGregor, 1923) of the inland individuals, *Anopheles costalis* is able to spread rapidly still further inland as soon as the warmer weather of the following spring and summer sets in. The inland winter-refuges, therefore, from an anti-anopheline view-point, are most important, constituting a "weak link" in the life-history of this species. This matter I have already dealt with in "A Report on the Anophelinæ of Mauritius, and on certain aspects of Malaria in the Colony."

THE ADULTS. The adult insects are rather small to medium-sized mosquitoes. To the unaided eye, the general body-colour is dark brown, and the costa shows well-marked areas of alternating dark and pale coloration, so that the wings are conspicuously spotted along the costa, as well as, to some extent, on the main wing surface. Female palpi with three white rings, the apical one broad. Male palpi with three patches of white hair-like scales on the apical joints. Femora and tibiæ of the legs of both sexes speckled with small blotches of white scales; articulations of all the leg joints with narrow white bands. These bands are distinctly seen when the insect is examined under the microscope or a hand-lens, but, with the exception of the narrow bands encircling the metatarsi of the front pair of legs, they are sometimes a little difficult to make out with the unaided eye. Note particularly, however, that if the insect is held in a good light, the bands

round the metatarsi of the front pair of legs are quite distinct.

Anopheles costalis is one of the commonest Mauritian anopheline species. It enters human habitations readily, and, although it feeds chiefly after sunset, it will often feed under natural conditions during the daylight hours also. In captivity, hungry specimens will feed whenever the opportunity occurs.

The Larvæ. The larvæ of *A. costalis* develop in all sorts of natural waters, such as rivers, rock-holes in river-beds, marshy ground, ponds, lakes, rain-water puddles, etc. They also develop in such artificial places as water-containing drains, irrigation reservoirs, borrow-pits, small holes in the ground, etc. They do not, however, live in tree-holes, in water-containing old tin cans and bottles, or in flower-pots. Moreover, they invariably demand sunlit breeding-places, and they will not develop even in natural waters which are heavily shaded; some sunlight on the breeding-place, at least for part of the day, seems essential to *A. costalis* larvæ. Unquestionably the larvæ find their most favourable conditions in the swamps and marshy ground at the sea-coast, where they may often be found in prodigious numbers; but very large numbers are commonly found also in ponds, ditches, small streams and the rock-holes in river-beds.

When first hatched the larvæ are black, but they are shorter than the larvæ of *A. mauritianus* at the same stage, and the thorax is distinctly wider than the width of the anterior segments of the abdomen. The larvæ rapidly lose their black colour in most cases, and most of the 2nd instar larvæ are usually dark or light brown. In the 2nd instar larvæ the thorax is even more markedly

wider than the anterior abdominal segments. Most of the 3rd instar larvæ are light brown or yellowish in colour, and, by the relative width of the thorax, the abdomen appears comparatively short. The 4th instar larvæ have the same general characters as the 3rd instar larvæ, but the posterior margin of the head is so closely appressed to the thorax that the larvæ have a characteristically "squat" appearance. The 4th instar larvæ of *A. costalis* are generally a pale yellow colour, but, within narrower limits, and far less frequently than is the case with the larvæ of *A. mauritianus*, the larvæ of *A. costalis* sometimes also show great colour variation. Some may be dark-brown, others greenish, and occasionally specimens have been found that were nearly white. These were developing in holes in coral rock on the shore in which rain-water had collected.

Where the larvæ of *A. costalis* are breeding in marshes near the coast at sea-level, they will often tolerate a fairly high degree of salinity. Saline water is, nevertheless, not particularly favourable to the development of the larvæ, and they do best in pure waters.

The exterior clypeal hairs of *A. costalis* larvæ, unlike those of *A. mauritianus*, are simple, *i.e.*, unbranched, and in the structure of the abdominal comb and palmate hairs they may be easily recognised under low magnification with the microscope. The leaflets of the palmate hairs carry a short terminal filament and the palmate hairs themselves are very transparent, so that they are somewhat difficult to see unless the body of the larva is turned on one side. The abdominal comb consists of numerous slender teeth of nearly uniform length and simple arrangement. (*Fig.* 20, *between pages* 78 *and* 79.) The characters of the clypeal hairs, the palmate hairs, and the comb taken together, make the identification of *A. costalis*

larvæ from those of the other three anopheline species a simple matter.

At the atmospheric temperatures of the coastal-belt the development of *A. costalis* is rapid, and, under favourable conditions, the development from the egg stage to the adult may be completed in about a fortnight. Under less favourable conditions the speed of development may be much slower, and development may be continued over many weeks.

The Eggs. *Anopheles costalis*, like the three other species, lays her eggs singly in batches of about 250. The egg is boat-shaped with lateral floats on each side. The enveloping membrane does not meet across the longitudinal centre of the egg, and the width of this free space, and the characters of the margin of the enveloping membrane, clearly differentiate the eggs of *A. costalis* from the eggs of the other species. (*See page* 105, *lines* 1-11).

Anopheles maculipalpis, Giles

Description and Bionomics

This large anopheline, which is only a little smaller than *A. mauritianus*, is the least common of the Mauritian *Anopheles*. It is by no means rare, but the particular demands it makes in the character of its breeding-places limits its distribution over the Island. It is commonest at sea-level on the coastal belt, but it has been found frequently also inland up to an altitude of 1200 feet.

Adults. *Anopheles maculipalpis* may be immediately distinguished from *A. mauritianus* by the fact that in the terminations of the hind pair of legs, the whole of the 3rd, 4th and 5th metatarsi are all white ; the white being continued on to the

2nd metatarsus to about its middle point. All the remaining leg joints are stippled with brilliant white dots. The costa of the wings is clearly broken into pale and dark areas, and the wings consequently have a spotted appearance. The palpi are black, flecked with white, and with three white bands, the two distal ones being broad, but not equally so. Except in captivity at the laboratory, *A. maculipalpis* was not found to feed during the day. It enters human habitations readily when these are situated near its breeding-places, but apparently it will not go far afield in search of food. The species was found only to breed in small collections of natural seepage-water, which percolated through hillsides or through the earth to lower levels from the river courses to form shallow pools in the ground or on rock surfaces. Experiments with *A. maculipalpis*, which I undertook in Mauritius, showed that this species is fairly readily infected with malaria, and it may therefore be regarded as a vector of the disease in the Island, although, owing to its scarcity, except in the vicinity of its limited and special breeding-places, it cannot be regarded as an important vector.

The Larvæ. *A. maculipalpis* lays her eggs on the particular types of natural water already mentioned. The type of water in which the larvæ are found may be broadly defined as collections of natural seepage-water, either situated in rocky-hollows or hollows in the earth. Rocky pools containing collections of natural seepage-water, free from vegetation, except fallen leaves or masses of spirogyra, often harbour very large numbers of the larvæ of this species along the coastal-belt. The particular type of breeding-place required naturally means that these breeding-places are never very extensive in area, and *A. maculipalpis*

larvæ are therefore only to be found in comparatively small pockets. It is, however, sometimes astonishing to discover just how many larvæ a small water-sodden area will accommodate, even when the depth of the water is only a few millimeters.

When the larvæ emerge from the eggs, they closely resemble the larvæ of *A. costalis*. In fact, at all the larval instars the larvæ of these two species are, to the unaided eye, morphologically so much alike that it is impossible, without long experience, to distinguish the one species from the other. After the 1st instar the colour of the larvæ provides a ready, but not always certain, character for their differentiation. The larvæ of *A. costalis* are usually of a yellow, green, or straw colour, while almost invariably the larvæ of *A. maculipalpis* are a deep brown. Only once during my investigations in Mauritius did we encounter a *maculipalpis* larva which was not completely brown. In that case the larva was deep green, and was captured in a rock-pool of seepage-water above the course of the Tamarin River, Black River District.

Fortunately, there is no difficulty in identifying *A. maculipalpis* larvæ under the low powers of the microscope, and it is advisable, even after long experience, to rely finally for the identification of the larvæ on the use of the microscope. Under the microscope the larvæ of *A. maculipalpis* may be immediately recognised from the other Mauritian anopheline larvæ by the specific structure of the abdominal comb, and by the fact that the palmate hairs depart from the normal type by being reduced to a tassel or brush-like form. The teeth of the comb are very irregular in size and are set on a spiny base (*Fig.* 20, *between pages* 78 *and* 79). In spite of the general resemblance of the larvæ of *A. costalis* and *A. maculipalpis*, macroscopically, these microscopical differences in the structure of the comb and

palmate hairs afford a straightforward and reliable means of distinguishing the two. *A. maculipalpis* develops from the egg to the adult more slowly than either *A. mauritianus* or *A. costalis*, and takes about a month, under optimum conditions, to complete its metamorphosis.

The Eggs. The eggs of *A. maculipalpis* are also of the common anopheline type, being boat-shaped with lateral floats, but there are sufficient differences in the form of the enveloping membrane, and other details to make immediate identification possible.

Anopheles funestus, Giles

Description and Bionomics

Anopheles funestus was discovered for the first time in Mauritius during the course of my work there in 1922. It occurs in Mauritius in enormous numbers at the coastal belt, but so far it has not been found in the Island above an altitude of 500 feet. The species occurs in Africa from sea-level to 5600 feet of altitude, so the likelihood of its extending its distribution in Mauritius is considerable. In many districts of Mauritius, *A. funestus* is undoubtedly the principal vector of malaria, and for the whole Island the species may be given the rank of the second principal vector—*A. costalis* ranking first in this respect. *A. funestus* normally seems only to be active at night, and there was no record of its seeking a blood-meal during the daytime, outside the laboratory. When hungry specimens were offered a blood-meal in the laboratory, however, they would readily feed at all times of the day or night.

Infection experiments with this species proved that *A. funestus* acquired infection with malaria with great facility.

The Adults. In appearance, *A. funestus* resembles a small *A. costalis*, but it is so much smaller than the average *A. costalis* that it is easily distinguished by persons with only a slight acquaintance with the two species. *A. funestus*, moreover, is somewhat darker in general colour than *A. costalis*. With a hand-lens, or under the microscope, the two species are recognised without difficulty. When a specimen of *A. funestus* is held in a good light and examined under a hand-lens, the most conspicuous specific characters are that the front pair of legs are free, or almost free, from pale bands on the articulations of the metatarsi, whereas the metatarsi of the front pair of legs in *A. costalis* are quite distinctly banded. Furthermore, in *A. funestus* there is no pale area in the fringe on the posterior margin of the wings at the termination of the 6th longitudinal vein, while in the wings of *A. costalis*, on the other hand, a pale area occurs in the fringe at the termination of the 6th longitudinal vein.

A. funestus chooses a large variety of natural waters as its breeding-place. In Mauritius, up to the present, the species has not been found breeding in any type of artificial water, and it seems to be restricted to rural surroundings, which, nevertheless, may actually be within city or town limits.

The Larvæ. The larvæ of *A. funestus* may be found in large numbers, at all times of the year, below an altitude of 500 feet in the coastal-belt. The larvæ occur in shaded streams and rivers, in ponds and lakes, in swamps and marshes, in ditches, rocky pools, and in neglected weed-encumbered drainage canals. They prefer shade, and are rarely found in direct sunlight. *A. funestus* larvæ are by far the most interesting Mauritian

anopheline larvæ, on account of their remarkable habits of concealment. A pond or other place in which hundreds of larvæ are present may often be thoroughly searched with dippers in the ordinary way without the collection of a single specimen. This is explained by the fact that long before the investigator reaches the breeding-place the slight tremors of the ground on which he treads are communicated to the pond, and all the *funestus* larvæ, who never venture far from weedy edges in any case, are warned of approaching danger, and dart back amongst the weed-roots, where they take refuge. Consequently, unless the dippers are thrust at an angle of about 45° down through the water to sweep the roots of the weeds, it is unlikely that the searcher will discover the presence of *A. funestus*. The habit of concealment is so strong in the larvæ of this species that not only do they hide most successfully, but if broad flat leaves dip into the water, and the worst fears of the larvæ are confirmed, they may even wriggle out of the water on to the damp leaf-surfaces in their efforts to escape capture. The larvæ are very easily recognised from those of the three other anopheline species. At all instars they are jet-black, with semi-transparent margins to the thorax and abdomen. The width of the thorax is much wider than that of the anterior segments of the abdomen, and the abdomen tapers sharply towards its posterior end. Further, their unusually well-developed and large palmate hairs on the abdominal segments, which break through the surface film when the larvæ lie at rest on the surface of the water, cause the dorsal aspect of the abdomen to glisten and to appear to be relatively dry. The leaflets of the palmate hairs bear terminal filaments that are as long, or slightly longer, than the individual leaflets, and there are large and conspicuous plates of chitin on the dorsal

surface of the abdominal segments. *A. funestus* larvæ also have a peculiar habit of attaching themselves by their mouth-parts to submerged or floating objects, such as leaves and plant-stems, when the water is violently agitated, and it is for this reason probably that a forceful blow with the dipper against the plant-roots facilitates the collection of specimens by breaking the hold of those who have seized the plant roots and stems. This habit is no doubt of great advantage to the larvæ in preventing them from being swept away by a rush of flood-water.

The pupæ of *A. funestus* are always much smaller than the pupæ of the other three species of anopheles, and they are invariably jet-black. In this case, therefore, the identification of the pupæ of *A. funestus* is possible.

When searching for *A. funestus* larvæ or pupæ, not only the vegetation at the sides of the breeding-place, but all floating objects, such as logs, fallen branches, and palm-leaves, should receive attention by thrusting the dippers *under* the floating or half submerged objects, as both larvæ and pupæ dive and cling to the under surfaces—the pupæ maintaining a hold by means of their respiratory trumpets.

The Eggs. The eggs of *Anopheles funestus* also conform to the usual type of anopheline egg, by having lateral floats. The eggs of this species are, however, considerably smaller than the eggs of the other three species, but, in addition to this feature, they possess structural details of the enveloping membrane which afford a ready means of identification. The eggs of *A. funestus* are sometimes found in enormous numbers floating amongst the vegetation at the sides of the breeding-place.

Notes on the Four Species of Anopheles found in Mauritius

Once the specific differences in the adults, larvæ and ova have been demonstrated, there is not the slightest difficulty in identifying the Mauritian species of anopheles. With the exception of the small black pupæ of *A. funestus*, the pupæ are so easily confused that it is inadvisable to attempt to identify the species from the pupæ. All pupæ should therefore be allowed to complete their metamorphosis, the identification subsequently being made from the emerged mosquitoes.

All the Mauritian anopheles will feed, become fertilised and oviposit in captivity if the two sexes are placed together in well-ventilated and shaded large insect-cages in which dishes of water have been placed after the female mosquitoes have had a blood-meal. A small bunch of nectar-containing flowers, or a few well-soaked raisins should be placed in the cages to provide the males with meals of fruit-sap.

In rearing anopheline larvæ in the laboratory, the question often arises as to which is the most suitable water. Naturally, it would seem that the water taken from the breeding-place where the larvæ were found should be the most favourable, but repeated experiments have convinced me that while such water at times acts admirably as a habitat, at other times the development of minute crustacean enemies, species of hydra, etc., and the likelihood of considerable changes taking place in the reaction of the water under laboratory conditions, prevents successful larval development.

During a period of my work in Mauritius, when it was necessary to rear large numbers of larvæ for experiments in connection with malaria infection, it was found that the most suitable water for the development of anopheline larvæ was the laboratory tap-water (Mare aux Vacoas supply), when to this was added one or two small clumps of grass with a small amount of earth attached to the roots. The reaction of the Mare aux Vacoas water was found to be alkaline, and the growth of the grass in the water maintained the right degree of alkalinity.

All the species of anopheles in Mauritius were found to breed in waters of either a neutral or alkaline reaction. None at any time were found to tolerate acidity.

In rearing the larvæ of *A. costalis* in the laboratory, care must be taken to ensure that the dishes holding the larvæ are exposed to direct sunlight, for at least the main portion of the day. In the case of *A. mauritianus* and *A. maculipalpis*, the dishes should be partially shaded, and with the larvæ of *A. funestus* the dishes must be completely, or nearly completely, shaded. The larvæ of all the species do better if glass is not interposed between them and the sunlight or the light from the sky—possibly on account of the opacity of glass to ultra-violet rays. This, of course, refers to the surface of the water and not to the bulk of the water at the sides of the glass dish.

Other points in connection with the successful rearing of larvæ in the laboratory and elsewhere are referred to under Part III, *page* 223 *et seq.*

THE AËDES MOSQUITOES OF MAURITIUS AND RODRIGUEZ

In the Island of Mauritius the Genus *Aëdes* is represented by four species, while only one species of *Aëdes* has been found in Rodriguez. These species are included in two of the Aëdes sub-genera, namely *Stegomyia* and *Aëdiomorphus*.

THE GENUS AËDES (Mg.)

ADULTS

"This genus, as a whole, is characterised as follows: Proboscis of uniform thickness throughout. Palpi of the female less than one-quarter as long as the proboscis. Antennæ distinctly plumose in the male, with the last two joints elongate; with moderately long verticils in the female, all the flagellar joints being about equal in length. Eyes distinctly separated. A continuous row of orbital bristles. Pronotal lobes widely separated. Pro-epimeral bristles about 4-6, in a posterior row overlapping the spiracle. Spiracular bristles absent. Post-spiracular, pre-alar, sterno-pleural and upper mesepimeral bristles all present and generally numerous. Postnotum without setæ. Eighth segment of the female abdomen retractile, a wide membrane between it and the seventh. Side-pieces of the male hypopygium with a lacuna of chitinisation extending the whole length of the inner side; claspers articulating in a horizontal plane. Tenth segment with tergites feebly developed; sternites simple, without teeth or spines. Hind tibiæ with the usual row of fine microscopical hairs just before the tip of the inner side, and also with a row of 7-10 longer hairs parallel with the first row and slightly more distally placed. First hind tarsal joint (first metatarsus) shorter than the tibia. Pulvilli absent. Front and middle claws of the

female nearly always toothed. Cell R_s (upper fork-cell) seldom much longer than its stem. Vein A_n (sixth longitudinal) terminating distinctly beyond the level of the base of R_s (second vein). Distinct microtrichia on the wing-membrane."

LARVÆ

"Mouth-parts not specially modified for predaceous habits, but the inner hairs of the mouth-brushes are generally more or less serrate. Antennal tuft generally at or before the middle. Abdomen without chitinous plates, except for the anal saddle, and sometimes small plates at the bases of the thoracic hairs. Eighth segment with a lateral comb or patch of scales. Siphon unmodified, short and stout, at most, four times as long as its breadth at the base, provided with a well-developed pecten and a single pair of ventral hair-tufts, situated about or beyond the middle; only very exceptionally with accessory dorsal hairs or hair-tufts."—(Edwards.)

KEY FOR THE IDENTIFICATION OF THE TWO MAURITIAN SUB-GENERA OF AËDES

Mosquitoes which have been previously found to belong to the Genus *Aëdes* may be referred to their respective sub-genera on the following characters:—

ADULTS

1. "Proboscis moderately slender, scarcely as long as the rather short femora. Palpi short in the female, normally longer than the proboscis in the male, the last two joints slender, upturned, and with very few hairs. Vertex with broad flat scales, few or no narrow ones on the nape. Thorax with conspicuous and well-defined ornamentation in the form either of lines or broad patches of silvery-white scales. Lower mesepimeral bristles absent. Male hypopygium usually without claspettes, unless these are represented by hairy basal lobes; no apical lobes; clasper with distinct terminal spine. Aedeagus divided into two more or less brush-like halves. Eighth segment of the female rather large, but distinctly retractile, the sternite not very prominent in repose; cerci rather short. Front and middle claws of the female either toothed or not .... *Stegomyia*.

2. "Proboscis slender, distinctly longer than the front femora. Palpi short in the female, usually no longer than the proboscis in the male, the last two joints and the tip of the long joint swollen and hairy, the last two joints turned very slightly downwards, the terminal joint generally a little more slender than the penultimate. Hair-whorls of the male antennæ rather irregular, the majority of the hairs projecting either dorsally or ventrally. Vertex and scutellum in many places are covered with flat scales; lower mesepimeral hairs are usually absent; the male hypopygium has no distinct claspettes, these being represented by hairy basal-lobes; while, on the other hand, the claspers are highly modified in most species, and even in the simple forms are distinguished by having the spine inserted before the tip. The hind claws are usually simple. ...... *Aëdiomorphus.*

LARVÆ

"Antennæ short, with single hair, and without spicules on shaft. Frontal hairs single. Abdomen with or without numerous stellate hair-tufts on dorsal surface; the 8th segment with a definite comb of teeth set in a single row. Siphon not much more than twice as long as broad; hair-tufts well developed and situated about the middle. The larvæ are often found in tree-holes, rock-holes and receptacles containing water in the vicinity of human dwellings .... *Stegomyia.*

"Antennæ short, with a well-marked hair-tuft and minute spicules on the shaft. Frontal hairs generally simple or only slightly branched, the anterior pair immediately in front of the lower. Abdomen without well-marked stellate tufts; the scales of the comb of the 8th segment in a triangular patch. Pecten usually with detached teeth outwardly, and the siphonal tuft is usually distinctly beyond the middle
(Edwards) .... *Aëdiomorphus.*"

KEY FOR THE IDENTIFICATION OF THE MAURITIAN SPECIES OF AËDES

ADULTS

1. Dorsal surface of the thorax conspicuously ornamented either with lines or broad patches of silvery-white scales 2
   Thorax not conspicuously ornamented; at most with white scales scattered indiscriminately and mixed with black and yellow scales 3

2. A single silvery-white stripe along the median line of the thorax; numerous patches of silvery-white scales on the lateral aspects of the thorax; legs with silvery-white bands .... *Aëdes (Stegomyia) albopictus*, Skuse.
   Two short narrow white lines, one on each side of the median line of the thorax, enclosed by two broader curved lines, forming a lyre-shaped design; numerous patches of white scales on the lateral aspects of the thorax; legs with white bands...... *Aëdes (Stegomyia) argenteus*, Poiret.
   Dorsal surface of the thorax almost entirely covered with silvery-white scales. White scales concentrated on the anterior lateral aspects of the thorax to form crescentic areas; legs banded with white
   Aëdes (Stegomyia) mascarensis, MacGregor.
3. Thorax not conspicuously ornamented, but with an admixture of scattered white scales. Free edge of the scutellum fringed with white scales. Wings with scattered white scales along the veins. Legs white-banded and stippled with white dots
   Aëdes (Aëdiomorphus) nigerensis, Theobald.

LARVÆ

1. Antennæ short, with a single hair, and without spicules on the shaft. Eighth abdominal segment with the teeth of the comb set in a single row 2
   Antennæ with a small well-marked hair-tuft, and minute spicules on the shaft. Eighth abdominal segment with the teeth of the comb arranged in the form of a roughly triangular patch. 4
2. Numerous stellate spine hairs (stellate tufts) on the abdomen and thorax; teeth of the comb simple when examined under the comparatively low powers of the microscope (2/3rds objective)
   A. (Stegomyia) albopictus, Skuse (*Fig.* 26, *between pages* 102 *and* 103, *and Fig.* 28, *page* 126).
   Comparatively few stellate spine hairs on the thorax and abdomen; teeth of the comb seen to be denticulate when examined under the low powers of the microscope (2/3rds objective) 3
3. Average number of comb teeth, eight; average number of pecten teeth, 15-20; pecten hair-tuft situated usually slightly beyond the last tooth of the pecten; the last tooth often a little removed distally from the preceding tooth; inferior denticles mainly half the length of the superior denticles
   A. (Stegomyia) argenteus, Poiret (*Fig.* 26, *between pages* 102 *and* 103, *and Fig.* 27, *page* 122).

Average number of comb-teeth, 10 ; average number of pecten-teeth, 8-12 ; pecten hair-tufts usually situated at about the same level as the last tooth of the pecten ; inferior denticles mainly half or more than half the length of the superior denticles
A. (Stegomyia) mascarensis, MacGregor (*Fig.* 27, *below*).

4. No stellate spine hairs on the thorax or abdomen ; teeth of the comb in two or more rows, arranged in a roughly triangular order ; pecten teeth : a line of closely set teeth, extending from the base of the siphon to about one-third of its length, beyond which are several widely-spaced larger teeth often, somewhat displaced from the main line of pecten-teeth. Siphonal hair-tuft situated just beyond the last pecten tooth, though sometimes situated mid-way between the last two teeth
A. (Aëdiomorphus) nigerensis, Theobald (*Fig.* 29, *page* 129).

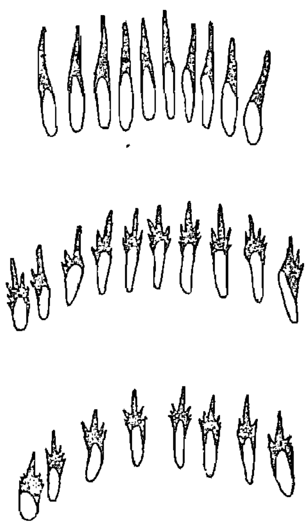


FIG. 27
Abdominal combs of Mauritian species of *Stegomyia Aëdes (Stegomyia) albopictus*; *A. (S.) mascarensis*; *A. (S.) argenteus*

In order to avoid complicating the subject, it will be sufficient to refer what is definitely established as an Aëdes mosquito, caught either in Mauritius or Rodriguez, to the foregoing specific identification tables (*pages* 119 *and* 120) instead of dealing with the single species of the Sub-Genus Aëdiomorphus—*A. (Aëdiomorphus) nigerensis*—under a separate table.

General Account of the Four Aëdes Species

Aëdes argenteus, Poiret

Description and Bionomics

This mosquito is easily recognised by its black and white coloration, and by the fact that the dorsal surface of the thorax is ornamented by four longitudinal white lines. The two central lines extend from the anterior margin of the thorax, run parallel, but terminate some distance before the posterior margin. The second pair of lines enclose the two parallel lines, and are arched towards the lateral aspects of the thorax; this ornamentation being commonly referred to as "the lyre-shaped design." The legs are black, but are conspicuously banded with white. The femora (particularly of the hind legs) bear a narrow white band which includes the tip; the tibiæ are all black; the tarsi of the fore and middle pairs of legs are ringed with two white bands; while the tarsi of the hind pair of legs have five white bands, the last two of which include the whole of the 5th metatarsi. The female palpi are short and black, the terminal joint being either tipped with white or all white. Male palpi; slender, as long or a little longer than the proboscis; second joints with broad white bands at their middle; third and fourth joints basally ringed with white. Abdomen of both sexes either black or brownish-black, ornamented with broad white bands across the abdominal segments, and with patches of white and yellowish scales on the lateral aspects. Lateral aspects of the thorax with numerous patches of silvery-white scales.

Adults. *Aëdes argenteus,* Poiret. Occurs in both Islands, and is widely distributed in the Tropics and sub-Tropics between 40° N. and 40° S. Although, elsewhere, the species has been found at an altitude of as much as 3000 feet, in Mauritius, for some inexplicable reason, it is apparently restricted to the coastal belt, in which, moreover, it has locally a very circumscribed distribution. In Rodriguez, however, the species is much commoner, and occurs all round the Island and up to an altitude of at least 800 feet. Why *Aëdes argenteus* should be much commoner in Rodriguez than it is in Mauritius, and in the latter Island occur in restricted localities at about sea-level only, is difficult to understand, especially as the mean summer and winter temperatures of Mauritius are slightly higher than those of Rodriguez. *Aëdes argenteus* is a species that is normally only active during daylight hours. It breeds mainly around human habitations in such places as rain-barrels, water-containing gutters, shallow wells, the saucers of flower-pots, old tin cans, broken bottles, puddles in the ground, rock- and tree-holes, etc. Both sexes freely enter houses, and the females are most persistent in their attack.

The species is an important one from the standpoint of public health, since it is the well-known vector of Yellow Fever in the countries where this disease occurs. It is, moreover, the vector of filariasis, and as filariasis is not uncommon in Mauritius, and probably to some extent occurs in Rodriguez also, *Aëdes argenteus,* together with *Culex fatigans*, should in this connection be wisely regarded as a noxious species. Which of the two species is mainly responsible in these two Islands for the transmission of the filariasis has not so far been determined, and this work merits the attention of the investigator.

Under particularly favourable conditions, *Aëdes argenteus* may develop from the egg to the adult insect in as short a time as 8-12 days. It develops rapidly in any favourable breeding-place, and the metamorphosis is generally completed in from a fortnight to three weeks. The species may be said to show a preference for the "artificial type" of breeding-place, and its development is most rapid in rain-water containing a large amount of organic matter from the bacterial decomposition of vegetable materials.

The Larvæ. *Aëdes argenteus* larvæ have the generic and specific characters given in the identification table on *pages* 119 *and* 121.

The abdomen carries a comparatively large number of spinose hair-tufts (stellate hairs), the comb-teeth on the 8th abdominal segment are denticulate, and the average number of these comb-teeth is 10 (*Fig.* 27, *page* 122). In Mauritius, the Aëdes species of mosquitoes which are found in tree-holes are *Aëdes argenteus*, *Aëdes albopictus* and *Aëdes mascarensis*. The larvæ of *Aëdes argenteus* may be readily identified from those of *Aëdes albopictus* by the fact that the teeth of the comb in the latter species, under moderate magnification, appear as simple teeth, while under the same degree of magnification, the comb-teeth of *Aëdes argenteus* are very conspicuously denticulate. *Aëdes argenteus* larvæ, unfortunately, are less easily distinguished from the larvæ of *Aëdes mascarensis*. The only available specific characters are those given in the table on *page* 121. In the case of these two species, the specific characters are admittedly not much to go on, and confirmation of the identification should, therefore, if possible, be carried out by rearing some of the larvæ to adults in the laboratory. In my experience, it is noteworthy, however, that the larvæ of these two

species were never found associated in the same breeding-place.

The Eggs. *Aëdes argenteus* lays her eggs singly on the water surface or upon damp materials which are in direct contact with water. The eggs are black, cigar-shaped objects about 1 mm. in length. The enveloping membrane is very thin and encases the egg evenly over its whole surface. At an

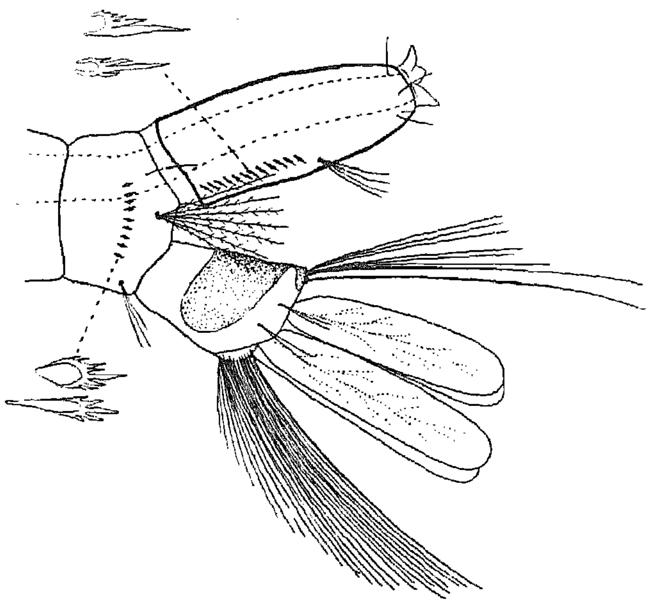


FIG. 28—SIPHON OF *Aëdes (Stegomyia) argenteus*

atmospheric temperature of 70° F., after the eggs have been in contact with water for about 60 hours, they become strongly resistant to desiccation. If the water of the breeding-place should then dry up, the eggs may remain viable for months and will hatch almost immediately they are once again in contact with water. Probably at higher atmospheric temperatures the resistant condition to desiccation is more rapidly attained. This ability of the eggs

to survive a long drought explains the sudden appearance of large numbers of *Aëdes argenteus* and certain other species whose eggs have the same powers of survival at the beginning of the "wet-season" in regions where definitely "dry" and "wet" seasons occur. The eggs of *Aëdes argenteus*, on account of the delicate and weakly developed enveloping membrane, are easily submerged, but submergence with this species does not in any way affect the development of the embryo, and the successful hatching of the eggs.

Aëdes albopictus, Skuse

Description and Bionomics

Aëdes albopictus is easily recognised by its black and white coloration, and by the fact that the dorsal surface of the thorax is ornamented by a single white stripe along the median line. Except for this well-marked difference in the ornamentation, the decoration of the rest of the body and of the legs is very similar to that of the foregoing species.

Aëdes albopictus is the commonest of the Mauritian Aëdes. It is found everywhere in the Island, from sea-level to the highest altitudes. It does not seem to occur on Rodriguez, in spite of the fact that in many cases it represented the only species of mosquito found on some of the islets around Mauritius. *Aëdes albopictus* may be termed "a semi-domestic" species. Its chief breeding-place is in tree-holes and rock-holes in the vicinity of human dwellings, which it enters freely during the daytime. Occasionally it is found breeding in artificial situations, such as water-butts, drains, old tins, old bottles, etc. It is a voracious and persistent species in houses, while in woods and forests it frequently attacks in swarms, the bites

inflicted being so painful that retreat soon becomes the main desire of the victim. Most water-containing tree-holes in Mauritius may be relied upon to contain a supply of *Aëdes albopictus* larvæ. *Aëdes albopictus* should receive attention as a possible vector of filariasis in the Island.

The Larvæ. Larvæ of *Aëdes albopictus* may at once be distinguished from those of the two other tree-hole breeding Aëdes (*Aëdes argenteus* and *Aëdes mascarensis*) by the fact that the comb-teeth under moderate magnification, appear simple, *i.e.*, not denticulate, and that they collectively project at a distinct angle from the sides of the abdominal segment on which they are set, whereas in the other two species the comb-teeth are denticulate and lie more or less appressed to the sides of the abdominal segment (*Fig.* 27, *page* 122). *Aëdes albopictus* larvæ are generally found in large numbers, and are often associated with the larvæ of *Aëdes mascarensis*, and the larvæ of *Orthopodomyia arboricollis*.

The Eggs. These are very similar in appearance to the eggs of *Aëdes argenteus*, but their morphology has not yet received careful attention, and there may be minor differences in the structure, which would enable the eggs of the two species to be identified.

Aëdes mascarensis, MacGregor

Description and Bionomics

Aëdes mascarensis is certainly one of the most beautifully-ornamented Mauritian mosquitoes. It is a black and white insect, with the dorsal surface of the thorax entirely covered by flat silvery-white scales, concentrated on the dorso-lateral aspects of the thorax into crescentic areas. The rear portion of the thorax and the basal abdominal

segments have a somewhat brownish colour, and the legs are conspicuously banded with white.

Aëdes mascarensis is a sylvan species. Apparently it does not go far afield from its breeding-places, which seem exclusively to be water-containing tree-holes in well-wooded or forest localities.

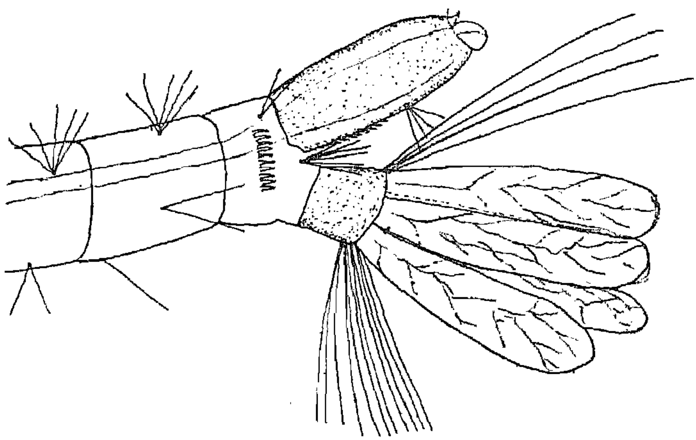


FIG. 29

Terminal end of abdomen of *Aëdes (Stegomyia) albopictus*, Skuse

It will, however, enter houses or sheds occasionally in order to get a blood-meal, when such houses or sheds are situated in the wood or forest. The species is only active during the daylight hours; it readily attacks man, but is not very persistent in its attack, and it is easily frightened off completely. Usually they attack singly and not in the large numbers as so often occurs in the case of *Aëdes argenteus* and *Aëdes albopictus*. *Aëdes mascarensis* may be recognised, even when the insect is in flight, owing to the striking contrast between the silvery-white thorax and the dark ground colour of the body.

The Larvæ. The larvæ of *Aëdes mascarensis* have only been found in water-containing tree-holes. They are fairly common all over the Island of Mauritius, but they do not occur in Rodriguez. Often the larvæ are associated with the larvæ of *Aëdes albopictus* and those of *Orthopodomyia arboricollis*, but in my experience they were never found in association with the larvæ of *Aëdes argenteus*. From the larvæ of *Aëdes albopictus* the larvæ of *Aëdes mascarensis* are very difficult to distinguish with the unaided eye ; but under the low powers of the microscope they are at once distinguishable, since the teeth of the comb of *albopictus* are simple, and those of *mascarensis* are denticulate (*see Fig.* 26). It will, moreover, be noticed, if the larvæ of these two species are compared under the microscope, that the combs of *Aëdes albopictus* project at a distinct angle from the segment to which they are attached, while the combs of *Aëdes mascarensis* appear to lie appressed to the surface of the segment (*Fig.* 30, *page* 131). In addition, stellate spine hairs are comparatively numerous on the thorax and abdomen of *albopictus*, whereas they are fewer and of a smaller size in *mascarensis*. With practice, it is possible to pick out the larvæ of either species from an association of the two without the aid of a microscope, by the difference in the stellate spine hair form.

The Eggs. The form of the eggs of *Aëdes mascarensis* are at present unknown. Like the eggs of the other species of this genus, they are no doubt laid singly on the water in the tree-holes or upon the damp surfaces of the walls of the holes. Investigations should be conducted to discover and describe these eggs, as it may be possible to find specific characters which will distinguish them from those of the two other Mauritian species of *Aëdes*.

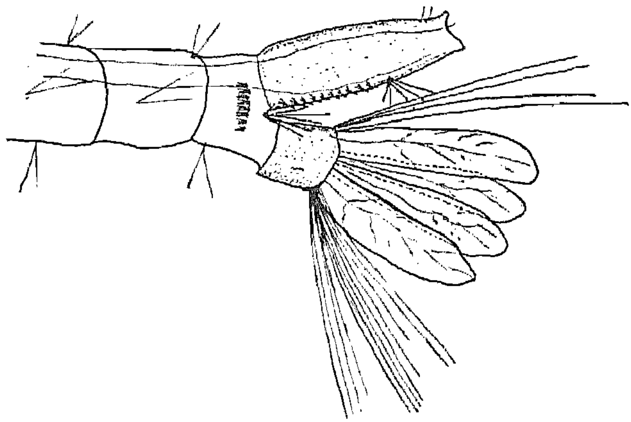


FIG. 30
Terminal end of abdomen of larva of *Aëdes (Stegomyia) mascarensis*, MacGregor

NOTES ON THE AËDES (STEGOMYIA) GROUP OF MAURITIUS AND RODRIGUEZ

The *Stegomyiæ* include some of the hardiest mosquitoes. Owing to the fact that the eggs of probably all the *Stegomyia* species are capable of resisting desiccation for long periods, the species may be easily distributed accidentally from one region, or even one country, to another by the accidental carriage of the eggs on the materials (wood, leaves, stones, etc.) on which the eggs may lie. In Mauritius the bodies of the larvæ are often enveloped by pseudo-parasitic fungi and protozoa to such an extent that the larvæ present a grotesque appearance. Apparently their development is not often adversely affected under these conditions, for experiments with the larvæ whose bodies were completely enveloped by these pseudo-parasites, have shown that pupation occurs quite normally, and that the mosquitoes which subsequently emerge are large and healthy specimens. While it has been proved that *Aëdes argenteus* so far is the only

Stegomyia which occurs on Rodriguez, the probability is that *Aëdes albopictus* will appear sooner or later in that Island also. All sorts of materials are exported from Mauritius to Rodriguez, and it is almost certain that a batch of eggs, or even adults of this hardy species, at some time will accidentally enter Rodriguez in this way. Flat Island and Gabriel Island (two small islands lying about 14 miles to the north-east of Mauritius), although inhabited regularly by about half-a-dozen men, a host of donkeys, numerous rabbits, rats and a few birds, already support a flourishing community of *Aëdes albopictus*, which, incidentally, was the only mosquito encountered on these two islets.

Aëdes argenteus has been proved to be the vector of filariasis, and attention might well be paid to the question whether to some extent the two other species are not also responsible for the transmission of the disease in Mauritius.

Aedes (Aëdiomorphus) nigerensis, Theobald

Description and Bionomics

In many ways this is a particularly interesting species. Its habits are quite dissimilar to those of the *Stegomyiæ*, since it seems to have only one type of breeding-place, namely, the rock-hole pools near the courses of rivers, where it is found as larvæ and pupæ, often in very large numbers. Occasionally the larvæ or pupæ occur singly in the cracks between rocks containing water, and in rock-drill holes in the same situations. *Aëdes nigerensis* differs from the species of *Stegomyiæ*, moreover, by the fact that the thorax of the adult bears no conspicuous ornamentation. The general colour of the thorax is dark brown, but under the microscope an admixture of white scales among the brown and black scales is noticeable. Along the free edge (posterior border)

of the scutellum, the scales are almost entirely white. To the unaided eye the wings appear pale brown, but again, under the microscope, white scales are to be seen dotted along the courses of the veins. The dark legs are distinctly banded at the articulations, and under the microscope the joints themselves are seen to be stippled with brilliant dots of white scales.

Proboscis of the male and female with a paler area at its middle. Palpi of the male with white bands at the articulations of the joints, a broad white band at the middle of the 2nd joint, and with scattered white scales on the 3rd and 4th joints. Palpi of the female; joints narrowly white-banded with brilliant white scales at the tips. Tip of the female abdomen pointed, and cerci conspicuous.

The adult females, under natural conditions, do not seem to bite man, but when starved in the laboratory, they could sometimes be induced to take a meal of human blood. *Aëdes nigerensis* was obtainable at all times of the year, but on account of some unknown factor governing its bionomics, it was only found breeding in isolated pockets, and it was therefore one of the less commonly encountered species—by no means rare, however. The rate of larval development is rapid and remarkably constant, all the larvæ being at the same instar in most of the breeding-places we encountered, and all reaching the pupal state almost at the same time. Obviously, the larvæ in each case must have hatched from a single batch of eggs, but even so, the close parallel development was quite extraordinary.

The Larvæ. The larvæ of *Aëdes nigerensis* are dark brown in colour with short rather stout siphons. The siphon differs from those of the *Stegomyiæ* in having the last teeth of the pecten

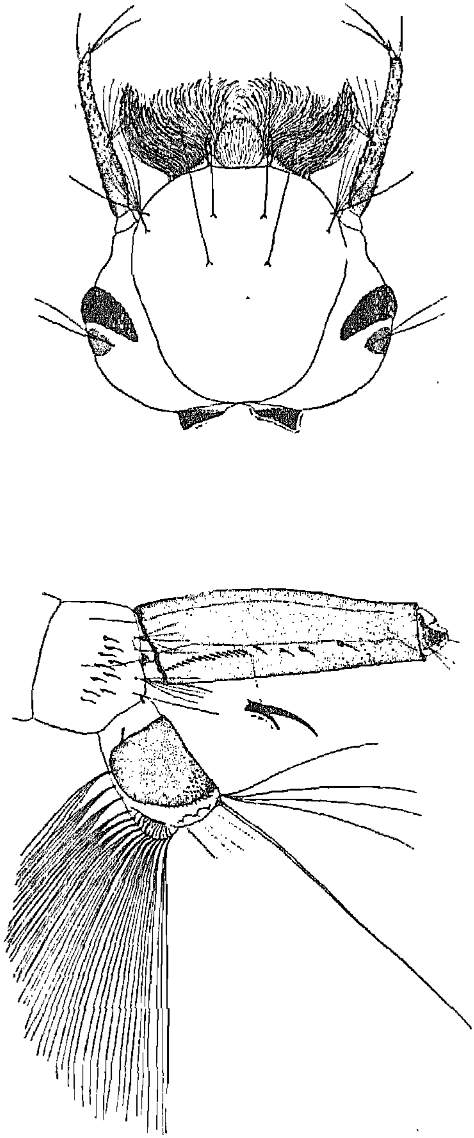


FIG. 31.—*Ochlerotatus nigerensis*, Theobald

The hair-tuft on the siphon has been omitted in the figure; its position is midway between the two last teeth of the pecten. (After F. W. Edwards.)

larger than the preceding teeth, and more widely spaced (*Fig.* 31, *page* 134). The antennæ carry well-formed hair-tufts, and the shaft of the antenna is minutely spiculed, two characters that distinguish the larvæ of *Aëdes nigerensis* from those of the *Stegomyiæ*.

The Genus Lutzia

Of this genus there is only one species that is found in Mauritius. It is absent from Rodriguez.

The Genus *Lutzia* is separated from the Genus *Culex* by the fact that mosquitoes of the former genus possess numerous lower mesepimeral bristles, whereas those of the latter genus normally have only one mesepimeral bristle. Moreover, the larvæ of *Lutzia* have their mouth-parts modified for predaceous habits, and the anal segment and siphon have a characteristic form.

There is no difficulty in the recognition of the single Mauritian species, *Lutzia tigripes*, Grandpré and de Charmoy, either as the adult or as the larva.

Lutzia tigripes, Grandpré and de Charmoy

Description and Bionomics

Lutzia tigripes is a large dull brown-coloured insect. To the unaided eye it appears to be an undecorated species, except for the fact that there are narrow yellowish bands across the abdominal segments, but if the insect is examined under the microscope or hand-lens, it will be noticed that the femora, and tibiæ especially of the fore and middle pairs of legs, and to some extent the other leg-joints also, are beautifully marked by dots and splashes of evenly arranged yellowish-white scales. It will be observed also that the legs are equipped with unusually long and regularly arranged spines. The numerous lower mesepimeral bristles are easily seen, and large

patches of yellowish-white scales occur on the lateral sclerites of the thorax.

Lutzia tigripes is to a great extent a sylvan species, but it is occasionally found elsewhere. While in Mauritius I was unable to obtain any record of its biting man, and it always refused to bite in the laboratory. Many female specimens were, nevertheless, captured after they had had a blood meal, but when the red blood cells in the mosquitoes' stomachs were examined, they were always found to be those of the goat. The species may at times bite man, as its habits in many ways resemble the habits of *Theobaldia annulata* in England. The species is to be found in all parts of Mauritius.

The Larvæ. The larvæ of *Lutzia tigripes* are among the most interesting mosquito larvæ in the Island. As they are predaceous, they are consequently always found in association with the larvæ of other species, unless it so happens that the number of the *tigripes* larvæ have recently exterminated the victimised species. The larvæ possess short siphons which are provided with unusually large valves. A line of hairs extends from the base to almost the tip of the siphon on its ventral aspect. The anal segment may be aptly termed chisel-shaped, since the tip of the segment terminates obliquely (*Fig.* 32, *page* 137). The mouth-parts are highly modified for the predaceous habit, the hairs of the mouth-brushes being cemented together to form prehensile fangs with which the prey is seized and held while it is consumed. The cementation of the hairs on the mouth-brushes is rather insecure, and the structure is easily studied by placing larvæ in hot, weak alcohol, or even hot water, when the individual hairs composing the fangs will separate. The

antennæ of the larvæ of *Lutzia tigripes* are also modified, being much reduced in size.

If the larvæ of *Lutzia tigripes* and those of some other species are placed together in a glass dish, the method of attack and capture and the consumption of the victims may be well observed.

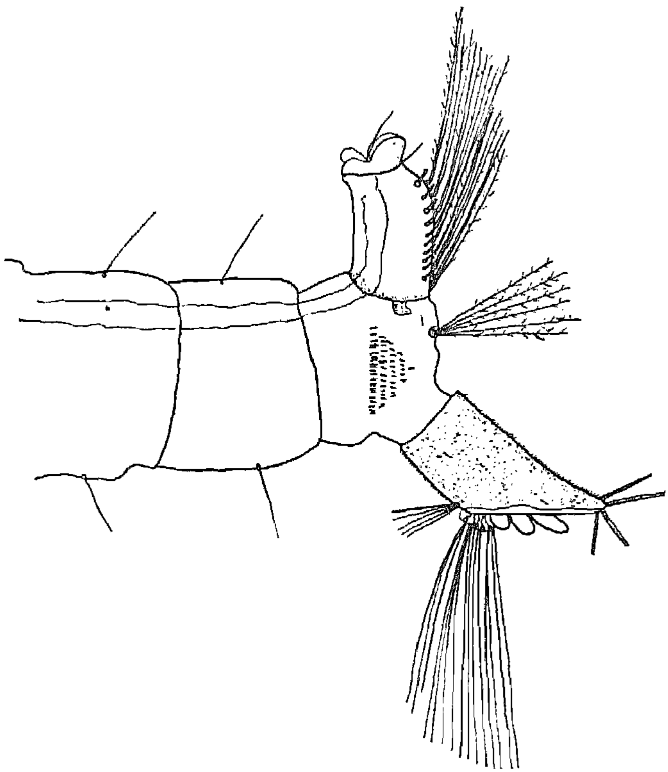


FIG. 32

SIPHON OF *Lutzia tigripes*, de Grandpré and de Charmoy

It is a gruesome spectacle. The larva of *L. tigripes* lies motionless until a larva of the other species comes within striking distance, and then, with the ferocity of a crocodile, the *tigripes* larva makes a sudden dart at the luckless victim, and with unerring precision seizes it by some part of the

head, thorax or abdomen. The captured larva usually struggles violently for a few seconds, but apparently adopting the philosophy of "Kismet," resigns itself to its appalling fate—to be slowly consumed alive until the devouring mandibles finally crush the large nerve ganglia in the thorax, and so put an end to the tragedy. I have often watched a larva which has been seized by the posterior abdominal segments retain its life for over twenty minutes, and during that period lose the whole of its abdomen and part of its thorax before the sudden cessation of the movements of the antennæ and mouth-parts indicated that death had occurred.

For some strange reason, hungry *L. tigripes* larvæ will often allow the larvæ of another species to lie in close contact with them if the latter lie quietly feeding, but at the first swimming movement the *tigripes* will turn like a flash and seize their prey. *L. tigripes* will frequently turn and savagely bite one of its fellow larvæ, but, either on account of some property of the integument of its fellows which prevents the fangs of the assailant from taking hold, or on account of the assailant only wishing to inflict punishment, I have never seen a *tigripes* larva retain its grip on or consume another of the same species. *L. tigripes* follows in the wake of other mosquito larvæ. Wherever the larvæ of some species of mosquito are developing, there the female *tigripes* choose to lay their eggs. Consequently, replacement of the first species by the larvæ of *L. tigripes* in certain breeding-places is often the case. There is thus, to some extent, a cyclic alternation of species noticeable in localities frequented by *L. tigripes*.

The larvæ mainly breed in rock-holes, tree-holes, and holes in the ground, but the species has occasionally been found in stagnant pools and marshy ground also. The larvæ will consume

culicine and anopheline larvæ, the larvæ of small chironomidæ, small nematode worms, live insects that have accidentally fallen into the water, and sometimes even young minnows—an amusing apostasy of a cherished ideal!

The surprising thing is that this voracious and widely-distributed species in Mauritius is, nevertheless, of no appreciable value in checking the development of other mosquitoes. There is clearly some factor that very successfully prevents *Lutzia tigripes* from becoming predominant, for, although the species would seem to have everything in its favour, *L. tigripes* is far from being the commonest species in the Island, while only seldom has it a chance of preying on the larvæ of *A. maculipalpis*, and rarely, if ever, of destroying the larvæ of the other anopheline species. This is explained by the fact that *L. tigripes* prefers the waters of small pools in sylvan situations to waters of large extent. The mere fact that the larvæ do not stalk their prey, and only capture those that come within striking distance, necessitates a high larval concentration, such as is usually found only in water-holes or waters of very restricted areas.

The Eggs. *L. tigripes* lays large cigar-shaped eggs which are laid on the water surface in raft-formation.

The Genus Tæniorhynchus

There is only one record of a species of this genus having been found in Mauritius. The record is unsatisfactory, as it is based on the capture of a single very much damaged specimen from Mare Rhoan, but, by the broad wing-scales, and by the absence of empodia, by the bright yellow colour of the body, and by certain other characters, the insect was, I think, correctly assumed to belong to the Genus *Tæniorhynchus*.

Consequently, I give here the characters of the Genus *Tæniorhynchus* as defined by Edwards, in the hope that other specimens of this mosquito may be captured at some future time.

Genus Tæniorhynchus, Arribalzaga

"This genus may be distinguished in the adult from *Culex* by the absence of empodia; from *Theobaldia* by the absence of spiracular bristles; and from *Aëdes* by the absence of a definite 'tibial-scraper' (a close-set row of bristles at the tip), by the non-retractile 8th segment of the female abdomen and the structure of the male hypopygium. The wing scales vary greatly in width in the different species, but are nearly always broader than in *Aëdes* or *Culex*. Although no more satisfactory distinctions can be discovered in the adults, the larval siphon is so wonderfully modified that on this character the genus is extremely well-marked."—(Edwards.)

The Larvæ

Larvæ of the species of *Tæniorhynchus* are characterised by having the siphon modified for sub-aquatic life (*Fig.* 19, *page* 78). The valves of the siphon are altered to form a pair of small saws by which the tissues of submerged plant stems are pierced so that the tip of the siphon may be inserted into the oxygen-containing plant vessels for the purposes of larval respiration. To capture the larvæ of this genus, it is therefore necessary to collect submerged plant stems on which the larvæ and pupæ may be found in the suitable breeding-places. Such breeding-places are almost always open ponds and marshes.

THE GENUS ORTHOPODOMYIA

In Mauritius the *Genus Orthopodomyia* is represented by one species, namely, *Orthopodomyia arboricollis*, d'Emmerez de Charmoy. It does not occur in Rodriguez.

The Genus Orthopodomyia, Theobald

ADULTS

"The adult characters are not very well marked, the most obvious being—(1) the presence of only two post-epimeral bristles ; (2) the small number of the bristles on the pre-alar prominence of the pleuræ ; (3) the length of the first tarsal joint, which in both sexes is distinctly longer than the remaining four together, while in most other mosquitoes it is only about as long ; (4) the rather long and stout antennæ of the male, all the joints being longer than usual ; (5) the short fourth joint of the front and middle tarsi of the female, which is much shorter than the fifth, and like that of the male, scarcely longer than broad. The very long fork-cells and the long first hind tarsal joint are also noticeable."

LARVÆ

"The genus is well characterised in the larval state by the absence of a pecten on the siphon, and the development, in the fourth-stage larvæ, of dorsal chitinous plates on the 6th, 7th and 8th segments of the abdomen. These two characters will distinguish the genus from all other mosquitoes. In addition, there are some small peculiarities, such as the development of a reddish pigment in the body of the larvæ (in the Mauritian species the pigment is of a sky-blue or blue-violet colour. M.E.M.), and the very long single lateral hairs on the thorax and abdomen."—(Edwards).

Orthopodomyia arboricollis, de Charmoy

Description and Bionomics

There is no difficulty in the recognition of this species, as it is one of the most remarkable of the Mauritian mosquitoes. It is a large species, the general body colour is a blackish-brown, the legs are conspicuously striped with white, and the wings are highly decorated with a mixture of yellowish-white and brown scales which give them the appearance of the wings of an anopheline mosquito. The proboscis in the male is marked at about its middle point with a band of white, while in the female proboscis this white band occurs further forward. In the male the palpi are about as long as the proboscis; those of the female half as long; in both sexes the palpi are decorated here and there with white scales. The antennæ of the female are of the normal type, but in the male the first two-thirds of the length of the antennæ are provided with long golden yellow hairs attached to the dorsal and ventral aspects of the antennal joints. Among these hairs there are also long white scales and longer dark-coloured hairs. The tip of the male antennæ terminates in a radially set group of hairs, beyond which the antennal joints are clad with fine short hairs. The thorax of both sexes is decorated with golden-yellow, white, and black scales and long black spines. Consequently, *Orthopodomyia arboricollis* is very easily distinguished from all other Mauritian mosquitoes.

It is a strictly sylvan species, and, except for specimens that had just emerged from pupæ, the adults were not encountered in the wild state. It does not attack man under natural conditions, and even experiments in the laboratory with starved

specimens failed to induce them to bite. Nevertheless, *O. arboricollis* is one of the commonest Mauritian tree-hole breeding mosquitoes, and the larvæ occur all over the Island. It seems probable, therefore, that the species is nocturnal in habit, and, if a blood-sucker (as the development of its proboscis would indicate), *O. arboricollis* very likely feeds on birds and small animals.

This species seems to breed exclusively in tree-holes.

The Larvæ. *Orthopodomyia arboricollis* larvæ are remarkable in many ways. They are among the most densely plumed and hairy mosquito larvæ known, and, consequently, their appearance, even to the unaided eye, is strikingly different from that of all the other Mauritian species. Many details of the larval ornamentation are extremely variable, nevertheless, especially as regards the plumose hair-tufts on the head. Among larvæ from the same batch of eggs the form of these hairs varies within wide limits (*see Fig.* 33, *page* 146).

Very often they are found associated with the larvæ of *Aëdes albopictus* and *Aëdes mascarensis*, from which their recognition presents not the slightest difficulty. In the young instars the larvæ are often of a lilac or sky-blue colour, but this colour is generally lost when the larvæ reach the 4th instar. At the 4th instar the colour of the larvæ is usually a semi-transparent neutral or yellowish hue, but when the larvæ are found in the highly-coloured water of mango tree-holes, their bodies not infrequently develop the same shade (sherry-brown). In the warm months of the year, the growth of the larvæ in the tree-holes is fairly rapid; but during the autumn and winter, development becomes almost completely suspended, and the larval state may thus continue for long periods. *O. arboricollis*, moreover, is a species

which, like certain other tree-hole mosquito larvæ, strikingly exhibits the phenomenon of " suspended development," when, in spite of a high atmospheric temperature and an ample food supply, the development of the larvæ ceases, and the larval state drags on indefinitely. With some species it has been shown that changes in the reaction of the water have a direct bearing on the induction of this state ; and that when the reaction of the water is suitably corrected development is resumed. Unfortunately, I was unable to investigate this phenomenon in the case of *O. arboricollis*, owing to pressure of other work ; but to show how remarkable a phenomenon it is, the following is an illustrative record.

On leaving Mauritius, in April, 1923, about 50 *O. arboricollis* larvæ which had entered the " suspended development " phase in my laboratory at Reduit, were placed in a large bottle which held over 250 c.c. of the water of the natural breeding-place. The water contained a large supply of food material in the way of the natural detritus of the tree-hole, and the mouth of the bottle was protected simply by a piece of mosquito-netting tied over it. Most of the larvæ were in the 3rd and 4th instar, and they were placed in the bottle about a week before I sailed. The atmospheric temperature was about 80° F. when the bottle containing the larvæ was placed in a well-ventilated position in my cabin, shielded from direct daylight but open to the fresh air.

The ship left Mauritius first for the east coast of Africa (Lourenço Marques), the journey taking about 12 days. At Lourenço Marques the steamer remained a week while a cargo of coal was embarked, and it then proceeded to Ceylon. Owing to the heavy freight, the journey was slow, very high atmospheric temperatures (as much as 103° F. in the shade) were encountered, and it was not until

nearly 6 weeks after leaving Mauritius that Ceylon was reached. The larvæ were examined each day, and the day before my arrival in Ceylon they were still found to be active and healthy. At this stage, unfortunately, disaster overtook the larvæ, as an over-zealous Lascar steward, in his ambition to have everything ready for disembarkation, emptied the bottle overboard, his excuse being that he thought it was "dirty water." But for this, I feel fairly certain that by taking advantage of the "suspended development" phase, I should have succeeded in my attempt to get the living larvæ to England.

In addition to the generic characters given on *page* 141, the larvæ of *O. arboricollis* may be recognised by the following specific characters:—

Anterior portion of the head carries (most frequently) eight heavily plumed hair-tufts, but in some cases these hair-tufts are not heavily plumed (*see* 2 *and* 3, *Fig.* 33, *page* 146).

Dorsal surface of the thorax and abdominal segments provided with paired spinose hairs. Lateral surface provided with hair-tufts and unusually long single hairs. Dorsal surface of the 6th, 7th and 8th abdominal segments often covered or partially covered with heavily chitinised plates. Comb composed of a row of long and a row of short teeth. Siphon without a pecten, but with a single hair-tuft situated at a point a little before the middle.

Anal glands ovoid (*see Fig.* 33, *page* 146).

It should be noted that the structure of the head plumes and the presence of the chitinised plates on the 6th, 7th and 8th abdominal segments of the 4th instar larvæ are both extremely variable characters. The plumes may be large and ornate or small and simple. The plates on the abdominal segments may be well developed, partially developed, or absent altogether, but even so, the

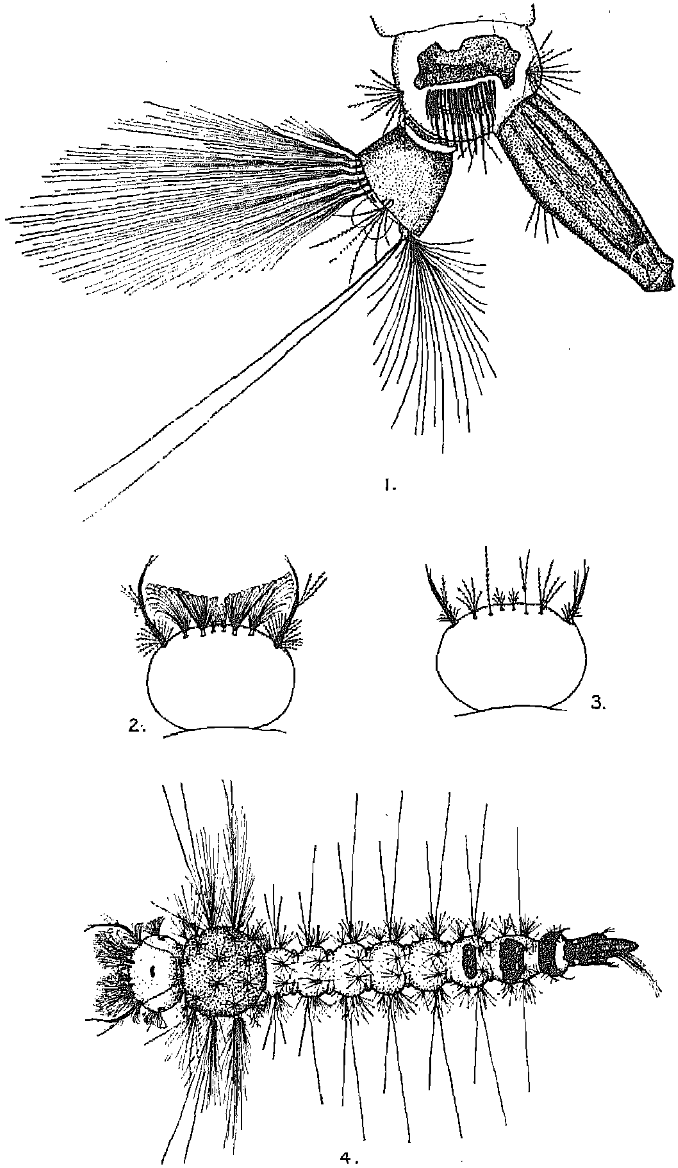


FIG. 33.—LARVÆ OF *Orthopodomyia arboricollis*, d'Emmerez de Charmoy
(1) End of abdomen of fourth instar. (2) Head, showing extreme variation, with dense plumes and long curved antennæ. (3) Head, showing opposite extreme of variation, with weakly-developed plumes and short, straight antennæ. (4) Fourth instar, larva showing complete development of the chitinous plates and head plumes.

general appearance of the larva strikingly differentiates it from all other Mauritian mosquito larvæ, and there is no difficulty in its identification.

The Eggs. Although several searches were made in the tree-holes, in which larvæ were found, for the eggs of this species, none, unfortunately, were discovered. In view of the fact that both the adults and larvæ have several unusual morphological characters, it is possible that the eggs of this species may also be found to possess characters which are specific.

The Genus Culex

Further study of both the adult and larval specimens I obtained from Mauritius and Rodriguez has shown that Mauritius is now known to possess eight definitely identified species of *Culex*. Ten species were recorded by me in 1922. The two species that are doubtful are (1) represented by unidentified larvæ found in a tree-hole at Reduit, to which no name can be given, and (2) *Culex sitiens*. The larvæ are in some ways very like those of *Culex fatigans*, except for the fact that the abdominal comb is either absent or very weakly developed. This is true not of a single larva, but of all that were found in the tree-hole. Moreover, *Culex fatigans* is not usually a tree-hole breeder, and it is, I think, most probable that the larvæ represent a species that has not yet been identified.

In 1908, d'Emmerez de Charmoy discovered a species which he called *Culex ronaldi*. Edwards identified this subsequently as *Culex sitiens*. While I was in Mauritius, Mr. d'Emmerez de Charmoy was kind enough to allow me to examine his specimen of the related larvæ, and when larvæ of this species were ultimately captured by myself they were recorded under the name of *Culex sitiens*. Finally, on my return to England, the related larvæ were

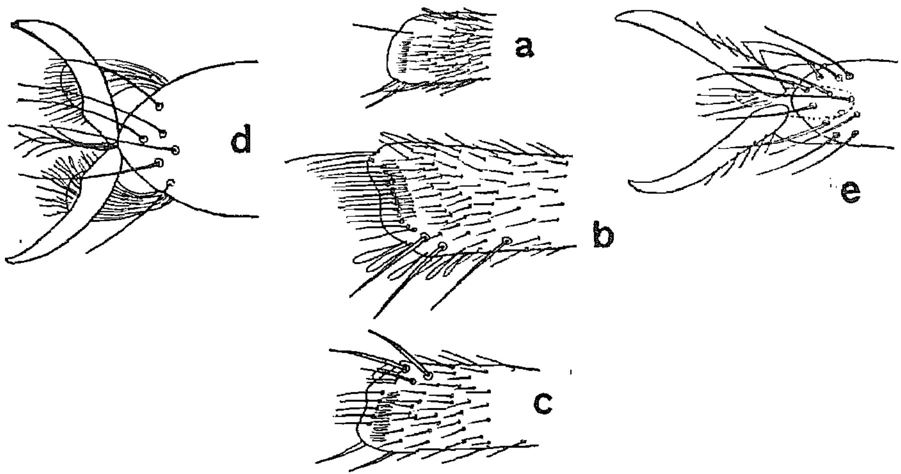


FIG. 34.—STRUCTURAL DETAILS OF EMPODIA AND PULVILLI

a, Tip of hind tibia, seen from the inner side, of *Culex hortensis* (scales omitted) × 65; **b,** the same structure in *Aëdes lepidonotus*; **c,** the same in *Theobaldia fumipennis*; **d,** tip of last tarsal joint of *Lutzia vorax*, showing claws, empodium and pulvilli × 340; **e,** tip of last tarsal joint of *Theobaldia annulata*, showing claws, small empodium and absence of pulvilli × 340

found by Edwards to be those of *Culex univittatus*, and the matter consequently became completely obscure. However, I was able to obtain from Edwards a mounted specimen of a larva definitely certified as that of *Culex sitiens*, and although it was not represented among the larvæ in my Mauritian collection, I feel fairly certain *(vide infra)* that we encountered similar larvæ in Mauritius. Nevertheless, I make the record of *Culex sitiens* from Mauritius one of the two doubtful records until further work confirms its presence in the Island.

The Genus Culex, Linnæus (Edwards)

Adults

"This genus, I find, is sharply distinguished from all other mosquitoes by the possession of distinct pulvilli. . . . I have examined a large number of species of this genus and find pulvilli present in all ; they do not vary much in size, but are naturally more easily detected in the larger species (*Figs.* 34*d and* 34*e*, *page* 148—made with the aid of a camera lucida) show clearly the difference in appearance under a sufficiently high power between a hairy empodium and a pair of true pulvilli. In the front and middle tarsi of the male, the pulvilli, like the claws, are elongated, and therefore less noticeable ; they may be seen, however, on the hind tarsi as well as on all the feet of the female. The only other mosquitoes which possess pulvilli are the genera which on other grounds have already been regarded as close allies of *Culex* : *Culiciomyia*, *Lophoceratomyia*, *Micrædes*, *Carrollia*, *Lutzia* and *Deinocerites* (including *Dinomimetes*). The first three or four of these should not be regarded as more than sub-genera of *Culex*, though the last two may be treated as distinct genera.

" The following characters are also common to most, if not all, species of *Culex* ; some of these will further help to distinguish the members of this genus from *Aëdes* : Eyes very narrowly separated, or even touching for a considerable length above the antennæ. Proboscis not or scarcely longer than the front femora. Male palpi, when long, always slender, with the last two joints upturned. Male antennæ always plumose, with the hairs spreading out evenly all round. Spiracular and post-spiracular bristles always absent. Usually only one lower mesepimeral bristle, or none ; very rarely two or three. Female abdomen bluntly ended, the cerci short and broad, 8th segment not at all retractile. Male hypopygium without claspettes or basal lobes to the side-pieces, but with sub-apical lobes bearing modified bristles. Tenth sternites ending in a tuft or comb of spines. Mesosome a paired structure with pointed processes. Claspers articulating in a more or less vertical plane. First joint of the hind tarsus as long as the tibia or slightly longer. Female claws always simple. Wings with distinct microtrichia on the membrane, cell R_2 markedly longer than its stalk in the female ; vein A_n ending much beyond the level of the base of R_s.

LARVÆ

" Antennæ with a distinct hair-tuft, which is generally well beyond the middle, the part of the antennæ beyond the tuft usually rather suddenly narrowed, and with few or no spicules ; two long pre-apical spines. Hairs of the mouth-brush simple. Frontal hairs rarely, if ever, single, and never placed one in front of the other. Anal segment with a complete chitinous ring (in the fourth stage only). Siphon with numerous ventral tufts or else greatly elongate."

The following is a list of the species of the Genus *Culex* which have been recorded from Mauritius and Rodriguez:—

Species		Where found
Culex fatigans, Wiedemann	......	Mauritius and Rodriguez.
Culex pipiens, Linnæus	......	Mauritius.
Culex univittatus, Theobald	......	Mauritius.
Culex sitiens, Wiedemann	......	Mauritius.
Culex tritæniorhynchus, Giles	......	Mauritius.
Culex quasigelidus, Theobald	......	Mauritius.
Culex simpsoni, Theobald	......	Rodriguez.
Culex thalassius, Theobald	......	Mauritius.
Culex rima, Theobald	......	Mauritius.
Culex species incerta found as larvæ		Mauritius.

Key for the Identification of the Species of the Genus Culex of Mauritius and Rodriguez

Adults

1. Light brown or tawny-brown species, without conspicuous ornamentation on either the thorax, proboscis or legs 2

   Dark brown species with conspicuous ornamentation on either the thorax, proboscis or legs : sometimes all these parts ornamented...... 5

   Blackish species 9

2. Tawny-brown species. Proboscis and tarsi without pale bands. Femora and tibiæ not longitudinally striped. Abdominal segments with complete basal bands 3

   Light brown species. Proboscis and tarsi without pale bands. Tibiæ with a more or less distinct pale lateral stripe 4

3. Mesonotal scales ochreous tinged. Upper fork-cell in the female about three times as long as its stem. An extremely common species in both Islands; enters houses in large numbers, and is active at night

   Culex fatigans, Wiedemann

   Mesonotal scales generally reddish-brown. Upper fork-cell in the female five times as long as its stem. A somewhat rare species in Mauritius, closely resembling *C. fatigans*, but found most often inland at the higher altitudes .... *Culex pipiens*, Linnæus.

4. Small light brown species. Narrow pale abdominal bands; hind tibiæ with a more or less distinct pale lateral stripe. A marsh-breeder. Rarely enters houses
Culex univittatus, Theobald.

5. Thorax, proboscis and legs with conspicuous markings 6
Proboscis and legs only conspicuously marked...... 7
Proboscis only conspicuously marked 8

6. Large brown species. Thorax conspicuously ornamented with a median stripe of golden-yellow scales, and two other stripes of similar scales extending from the lateral aspects of the thorax to join the lower end of the median stripe. Abdominal segments black or deep brown, with broad white bands. Proboscis with a pale band at its middle. Legs with distinct narrow bands on the articulations of the femora and tibiæ. Occurs very commonly in Rodriguez; but, so far, has not been found in Mauritius .... *Culex simpsoni*, Theobald.

Large brown species: proboscis, palpi, thorax and legs ornamented. Proboscis with a yellow band at its middle. Palpi of male with pale rings at the articulations. Thorax with a broad band of pale coloured scales across its middle. Narrow white bands at the apex of the 1st, 2nd, 3rd and 4th metatarsi. Femora and tibiæ evenly speckled with white dots. A marsh-breeder; fairly common in Mauritius; not found in Rodriguez
Culex quasigelidus, Theobald.

7. Large tawny-brown species. Proboscis with a broad whiteish band at its middle. Thorax and legs with distinct narrow pale yellow bands at the joints. A marsh-breeder. Common in Mauritius; not found in Rodriguez .... *Culex thalassius*, Theobald.

8. Smaller dark brown species. Abdominal segments blackish-brown. Proboscis banded at its middle with yellowish-white scales. Legs not conspicuously ornamented, but under the microscope the femora are seen to have a distinct speckling of pale scales in front. Upper fork cell with its base nearer the apex of the wing than that of the lower. (Whether this species occurs in Mauritius or not still has to be decided by further investigations.)
Culex sitiens, Wiedemann.

Smaller medium brown species. Abdominal segments brown. Proboscis with a band of yellowish-white scales at its middle. Legs not speckled. Mesonotum with

dark reddish-brown scales, no pale ones on the disc; upper fork-cell with its base distinctly nearer the wing base than that of the lower; mid tibiæ dark in front. A swamp breeder; common in Mauritius; not found in Rodriguez .... *Culex tritæniorhynchus*, Giles.

9. Blackish species; not conspicuously ornamented on any part of the body. Dorsal surface of the thorax brown; abdomen black or dark brown, with narrow white bands on the apices of the segments.
   Lateral aspect of the thorax (pleuræ) marked with horizontal blackish lines. Breeds in rock-holes or holes in the ground near rivers. Fairly common in Mauritius; not found in Rodriguez ...... *Culex rima*, Theobald.

(LARVÆ)

1. Siphon of moderate length; from 4-5 times the breadth at the base, broader at its middle than the breadth at its base 2
   Siphon of moderate length, long, or very long, tapering evenly from base to apex; therefore broadest at its base 3

2. Siphon about four times as long as its breadth at the base. Four pairs of siphonal hair-tufts; first pair set close to the last tooth of the pecten, followed by two other pairs of similar large branched hairs; these three pairs of hair-tufts situated ventrally on the middle portion of the siphon. Third pair of hair-tufts, placed dorso-laterally between the last pair of branched hairs. Termination of the siphon pointed. Anal gills about as long as the anal segment. Breadth of the head and thorax in 4th instar larvæ about equal. Body-colour, uniform; usually straw-coloured larvæ. Breeding-places: numerous types, but preferably rain-water containing decomposing vegetable matter near human dwellings. Larvæ extremely common both in Mauritius and Rodriguez .... *Culex fatigans*, Wiedemann.

   As above, with the exception that the proportion of the length to breadth of the siphon is about 5 to 1, and that the small pair of hair-tufts of the siphon is situated dorso-laterally between the 2nd and 3rd large hair-tufts. A somewhat rare species in Mauritius, found occasionally in the higher and cooler parts of the Island
   Culex pipiens, Linnæus.

3. Hair-tufts of the siphon large and well-branched 4
Hair-tufts of the siphon small and weakly-branched; each hair-tuft generally with not more than 5 short hairs 5

4. Siphon, in 3rd and 4th instar larvæ, about five times as long as its breadth at its base. Five pairs of siphonal hair-tufts; four pairs of large, plumed tufts situated ventrally. Position of the 1st pair of hair-tufts well beyond the last tooth of the pecten; space between the plumed hair-tufts almost equal; 4th hair-tuft near the tip of the siphon; 5th hair-tuft small, situated dorsally almost opposite the 2nd plumed hair-tuft. Valves of the siphon more than usually large. Pecten with 10 teeth; comb on 8th abdominal segment consists of a single line of from 7-8 large teeth. Anal gills; ventral pair long, about as long as the anal segment; dorsal pair short, about half this length. Tips of antennæ dark, middle portion conspicuously white. Large plumed hairs near the base of the antennæ. Breeding-places: ponds, swamps and grass-clad rivers. Species fairly common in Mauritius .... *Culex quasigelidus*, Theobald.

Siphon about 6 to 7 times as long as the breadth at the base. Six pairs of siphonal hair-tufts; five pairs large, but unplumed, situated ventrally; 1st pair situated just beyond the last tooth of the pecten at a point about one-third from the base. Remaining four pairs of ventral hair-tufts nearly equally spaced; terminal hair-tuft smaller than the preceding pairs, and situated at a point near the apex of the siphon. 6th pair of siphonal hair-tufts situated laterally, in a position mid-way between the 4th and 5th ventral tufts. Pecten: 12-14 teeth. Comb of 8th abdominal segment composed of from 75-80 small teeth. Anal gills short, and of ovoid form. Antennæ comparatively short; tips dark. Breeding-places: marshes and swampy pools. Common in Mauritius .... *Culex thalassius*, Theobald.

Siphon of moderate length or short; about 2-2½ times as long as its breadth at the base. Six pairs of large siphonal hair-tufts; 1st pair situated opposite the last tooth of the pecten; remaining four ventral pairs, fairly evenly spaced. 6th pair of hair-tufts situated at a point opposite the 3rd and 4th ventral pairs. Pecten with from 9-11 moderately long teeth. Anal gills small, and of ovoid form. Head pale; antennæ, the larger part of the shaft pale, darker at the extreme base and along the apical part between the tuft and the tip. Comb of the 8th abdominal segment composed of about 30 small teeth

arranged in a roughly triangular patch. Breeding-places : salt-marshes and other swampy situations

Culex sitiens, Wiedemann.

(Whether this species occurs in Mauritius or not still has to be decided by further investigations.)

5. Larvæ with numerous small siphonal hair-tufts composed of from 2-5 short hairs 6

Larvæ with numerous small siphonal hair-tufts composed simply of two hairs—sometimes only one 7

Larvæ with inconspicuous siphonal hair-tufts and a few minute scattered hairs—sometimes no hair-tufts or hairs visible 8

6. Siphon about 6 to 7 times as long as the breadth at the base. Six pairs of siphonal hair-tufts, composed of from 2-5 short hairs. Five pairs of hair-tufts placed ventrally, one pair placed dorso-laterally. 1st pair of ventral hair-tufts situated slightly beyond last tooth of the pecten ; remaining four pairs fairly evenly spaced. 6th pair (dorso-lateral hair-tufts) placed at a position between the 4th and 5th ventral hair-tufts. Pecten : 12-15 rather long teeth ; last tooth of the pecten about one-third from base. Comb : a triangular patch of from 35-45 teeth. Thorax broader than the head. Anal gills, short and conical, about half as long as the anal segment. Bodies of larvæ often striped. Breeding-places : marshes and swampy pools. Common in Mauritius

Culex tritæniorhynchus, Giles.

7. Siphon about 8 to 9 times as long as the breadth at the base. Five pairs of siphonal hair-tufts, composed of short double or single hairs. Arrangement of these hairs often varies considerably. General arrangement : first three pairs ventral, then two pairs dorso-lateral. Pecten : 10-13 teeth. Comb : a triangular patch of about 50 well-developed teeth. Anal gills small. Bodies of larvæ often striped. Breeding-places : marshes and swampy pools. Common in Mauritius ...... *Culex univittatus*, Theobald.

8. Larvæ with extremely long and slender siphons, about 10 to 11 times as long as the breadth at the base...... 9

Larvæ with moderately long and slender siphons, about 7 to 8 times as long as the breadth at the base 10

9. Siphon about 10 to 11 times as long as the breadth at the base. Siphonal hair-tufts minute ; five pairs all ventrally

situated. First four pairs fairly evenly spaced, but space between the 4th and 5th pairs considerably greater. These hairs present in some larvæ, absent in others, but 1st siphonal hair-tuft nearly always present, situated close to the last tooth of the pecten. Pecten: 10-11 teeth. Comb: triangular patch of from 75-80 rather long teeth. Anal gills, moderate; about three-quarters the length of the anal segment. Body colour of the larvæ usually dark; antennæ entirely dark. Breeding-places: rock-holes and holes in the ground near rivers. Common in Mauritius at certain times of the year; not very common at other times .... *Culex rima*, Theobald.

10. Siphon about 7 to 8 times as long as the breadth at the base. Siphonal hair-tufts minute; five pairs; 1st and 2nd pairs ventral, 3rd and 4th pairs dorso-lateral, 5th pair lateral—sometimes ventral. 1st hair-tuft nearly always present, situated close to last tooth of pecten; other hair-tufts often absent. Pecten: 11-13 teeth. Comb: triangular patch of from 30-35 teeth. Anal gills: dorsal pair about as long as the anal segment; ventral pair little more than half as long. Antennæ, dark at the base and tip, pale in the middle. Body-colour of the larvæ, pale. Breeding-places: ponds, road-side puddles, and rivulets in Rodriguez, where the species is extremely common .... *Culex simpsoni*, Theobald.

Of the five genera in Mauritius and Rodriguez, the Genus *Culex* contains the species whose identification will perhaps present the most difficulty. However, once the different species have been recognised, their subsequent identification will not be difficult. The fact that many species of *Culex* are devoid of conspicuous ornamentation is apt at first to induce the feeling on the part of the investigator that " only an expert " can differentiate the species. Nevertheless, it will be found that however similar the species of the Genus *Culex* may at first appear to be to the unaided eye, microscopical examination, in the majority of cases, will reveal distinct specific characters which are often hardly less striking than the specific characters of other mosquitoes that are visible to unaided vision.

Culex fatigans, Wiedemann

Description and Bionomics

Culex fatigans is undoubtedly the commonest mosquito in both Mauritius and Rodriguez. It abounds in the localities at sea-level, and is no less common even in the localities at high altitude. It is a nocturnal species becoming active about sunset, and continuing its activities until sunrise. *C. fatigans* enters houses readily, and may, in fact, be considered a "domestic" species. It is a fairly large mosquito of a tawny-brown colour. The dorsal surface of the thorax has a reddish-brown appearance. The proboscis and legs are unbanded, and there is no conspicuous ornamentation on any part of its body. Consequently, taking into account these characters, and the microscopical characters given in the identification table on *page* 151, together with the fact that *C. fatigans* is a nocturnal species commonly found in houses, there will be no difficulty in its recognition. In the localities where either *Aëdes (Stegomyia) albopictus* or *Aëdes (Stegomyia) argenteus* occur, the human population is subjected to continuous persecution by mosquitoes, since these *Stegomyia* species are active during the daytime, and when they cease their activities, *C. fatigans* assumes hers. Were it simply to lessen this persecution, which is real enough at times to make comfort impossible, measures for the control of *Culex fatigans* and these two species of *Stegomyia* would be most desirable, but as these species in Mauritius (and possibly to some extent also in Rodriguez, as far as *C. fatigans* and *Stegomyia argenteus* are concerned) are, moreover, the vectors of filariasis, the control of *C. fatigans* and these *Aëdes* species is essential. Filariasis,

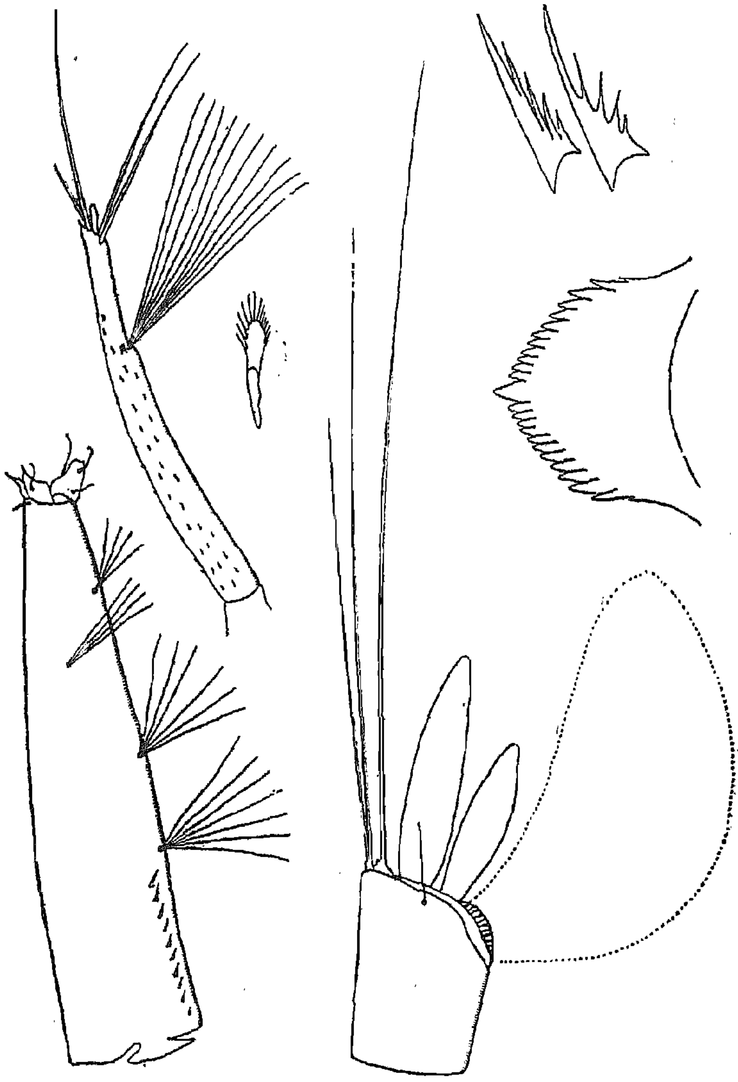


FIG. 35.—SIPHON AND ANATOMY OF TERMINAL END OF *Culex fatigans*, Wiedemann

(After P. J. Barraud: "A Revision of the Culicine Mosquitoes of India")

as it is manifested by elephantiasis, is not uncommon in Mauritius, and it is, I think, likely that many of the inhabitants harbour the microfilariæ in their blood without experiencing other than vague symptoms of disease. In each case either *C. fatigans* or one of these two *Stegomyia* may be held responsible for the infection, and if the damage they inflict is at present obscure, the need for control measures is none the less urgent. Fortunately, as *C. fatigans* and its *Aëdes* co-vectors are "domestic" or "semi-domestic" species (*i.e.*, species which breed and flourish near human dwellings, as opposed to the "wild" species of mosquito, whose breeding-places are in rural natural waters), the anti-measures for their control may be most successfully undertaken by all members of the population. Such measures are simply the abolition and prevention of suitable breeding-places.

The Larvæ. *C. fatigans* chooses "artificial" waters as its most favoured breeding-place. These may be the stagnant water accumulated in the catch-pits of drains and rain-water gutters, water-barrels, water-tanks, ornamental ponds, swampy ground near houses, and, in fact, any water near human habitation in which there is organic matter to act as a food supply. Nevertheless, *C. fatigans* may often be found breeding vigorously in natural waters remote from human communities.

The larvæ of this species of *Culex*, and its near relative, *C. pipiens*, is easily recognised from all the other *Culex* larvæ of both Islands by the fact that the siphon is wider at its middle than the width at the base. In the case of the other species, the siphons are all widest at the base and taper towards the tip. The siphon carries four pairs of hair-tufts, which are collectively set on the dilated middle portion and tip (*Fig.* 35, *page* 158).

The larvæ are usually of a straw-colour, and the width of the head and thorax is about equal. The development of *C. fatigans* larvæ is at all times rapid, and under optimum conditions, the larval stages may be completed within a week. Consequently, swarms of *C. fatigans* may develop in any neglected water in or near dwellings. All unnecessary water-containers should be abolished; receptacles, such as catch-pits, and drains, etc., should have a little paraffin oil poured upon the contained water once a fortnight; water-barrels and water-tanks should be equipped with closely fitting and well maintained metal-gauze screens (preferably zinc, copper or phosphor-bronze); ornamental ponds should be stocked with small fish, and the sides of the pond kept clear of vegetation. Individual attention to these matters on the part of the population of both Mauritius and Rodriguez would be sufficient practically to exterminate *C. fatigans* as a pest. *C. fatigans* and *Aëdes argenteus* are, above all others, the easiest mosquitoes to get rid of, since they have become adapted to taking advantage of man's hitherto ignorant carelessness in providing them with easily acquired breeding-places. Take steps to withdraw this unintentional courtesy, and the numbers of *C. fatigans* and *Aëdes argenteus* will vanish, greatly to the advantage of the community.

The Eggs. *C. fatigans* lays her eggs in raft-formation. The raft is pointed at both ends and roughly resembles the shape of a boat.

Culex pipiens, Linnæus

Description and Bionomics

This species is considerably rarer in Mauritius than *C. fatigans*, from which it can only be distinguished by the microscopical characters given

on *page* 151. It was found occasionally in the higher parts of the Island in cow sheds. It is questionable whether *C. pipiens* very often bites man under natural conditions, and it certainly is not a species that constitutes a pest. In Mauritius, as elsewhere, *C. pipiens* seems to prefer to feed on animals.

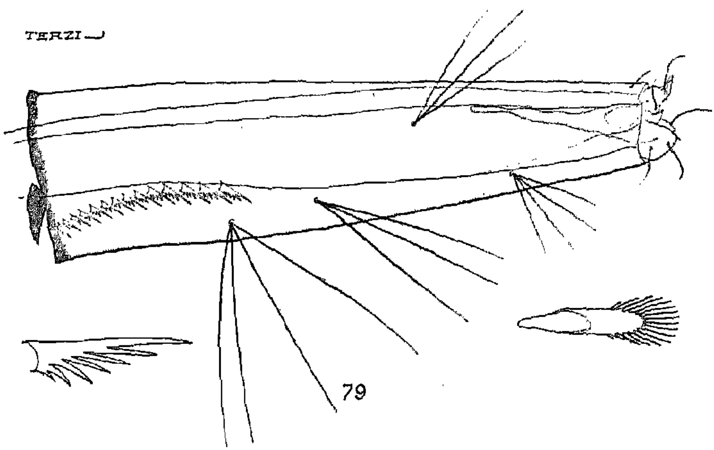


FIG. 36.—SIPHON OF *Culex pipiens*, Linnæus

(After W. D. Lang: "A Handbook of British Mosquitoes")

The Larvæ. The larvæ of *C. pipiens* resemble the larvæ of *C. fatigans* closely. The siphon is broadest at its middle point—not, perhaps, quite so broad as the siphon of *C. fatigans*—and the proportion of its length to breadth is slightly greater than that of *C. fatigans* (*Fig.* 36, *above*).

The Eggs of *Culex pipiens* are indistinguishable from those of *Culex fatigans*, but the female prefers to lay in collections of rain-water containing vegetable matter in the process of disintegration by bacterial decomposition—such water, for instance, as is often contained in horse-troughs and drains from stables. The species will, however, often breed very well in sewers and the effluent from septic tanks.

Culex univittatus, Theobald

Description and Bionomics

C. univittatus, and the remaining species we have to consider, may be classed as "wild" species. In Mauritius and Rodriguez (with the possible exception of *Culex simpsoni* in Rodriguez) they only enter houses accidentally, and the principal sources of food supply are the sap of plants and the blood of animals and birds. Nevertheless, some of the species will attack man voraciously in the open. *C. univittatus* is a small species in some ways not unlike a small *C. fatigans*, from which it may be readily distinguished, however, by the fact that it is a paler brown and has none of the reddish coloration on the thorax. It is also a more delicately made species with particularly long and slender legs, the hind tibiæ possessing a more or less pale lateral stripe. Otherwise it is not conspicuously marked. Along the coastal districts of Mauritius, *C. univittatus* is exceedingly common, frequenting the low-lying marsh lands, where it is sometimes found in enormous numbers.

The Larvæ. The larvæ of *C. univittatus* are most often found in marshes which are open to direct sunlight and are not overhung by trees. They often occur in very large numbers in small marshy pools with grass-clad edges. Not infrequently, in such situations, they are associated with the larvæ of *A. costalis*, *C. thalassius* and *C. tritæniorhynchus*, and in common with the larvæ of the two latter species, the larvæ of *C. univittatus* are easily frightened and will remain submerged for a considerable time. While submerged, both *C. univittatus* and *C. tritæniorhynchus* larvæ adopt a somewhat unusual method of escaping pursuit.

In the region of Pointe aux Sables (Black River District of Mauritius), many of the marsh-pools are shallow, three to four inches deep, with yellow sandy bottoms. Small stones, dead grass-stalks, and other objects lying on the bottom of the pool give the yellow sandy background an irregular speckled appearance, and here the mosquito investigator may fully realise the significance of the oftentimes striped yellow bodies of the larvæ. The striped bodies blend so perfectly with the speckled yellow background of the bottom of the pool that, while the larvæ remain still, either at the surface or at the bottom, they are almost invisible.

However, not content with the measure of safety ensured by their protective coloration, when alarmed, the larvæ dive in the usual way, but, in a quite extraordinary way, after diving to various depths, they very often at once proceed to scurry in a horizontal direction through the water so that when the effort of their flight has ended, they are sometimes ten or more feet on one side or the other of their former point of suspension at the surface.

For this reason, at times, when there are only a comparatively few larvæ in the breeding-place; their capture demands a certain ingenuity on the part of the collector, but usually the larvæ of these three marsh-breeding species,

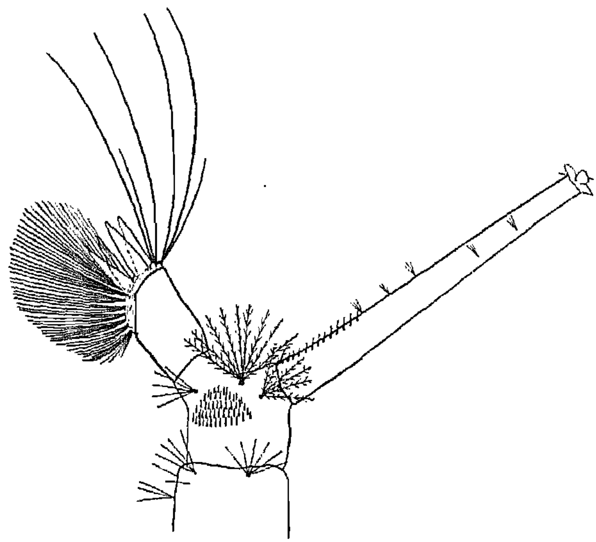


FIG. 37

SIPHON OF *Culex univittatus,* Theobald

Culex univittatus, Culex tritæniorhynchus and *Culex thalassius,* are so numerous that the sweep of the "dipper" results in the capture of many specimens.

C. univittatus larvæ have long slender siphons, on which there are usually five pairs of hair-tufts composed of short double or single hairs (*Fig.* 37, *above*). The bodies of the larvæ are often transversely striped.

Culex univittatus larvæ were found to occur in the marshes in all parts of the coastal belt of Mauritius.

Culex tritæniorhynchus, Giles

Description and Bionomics

This species, although commonly associated as larvæ with those of *C. univittatus,* is easily distinguished as the adult from *C. univittatus* by the fact that the proboscis of *C. tritæniorhynchus* is ornamented with a band of yellowish-white scales well beyond its middle. The mesonotum is clad with reddish-brown scales unmixed with pale scales on the anterior dorsal surface. On the posterior dorsal surface of the thorax, however, there are four short lines of golden-yellow scales; two of these being arranged on each side of the median line, while the other two lines of scales occur one on each side of the posterior lateral margins of the thorax. The general body-colour of *C. tritæniorhynchus* is a chocolate-brown, and the scale-bands on the abdominal segments are nearly white; the legs are dark brown, with inconspicuous light bands on the articulations of the middle and hind pairs, but in the front pair of legs the tarsal joints are fairly conspicuously banded. *C. tritæniorhynchus* is a small to medium-sized species.

The Larvæ. *Culex tritæniorhynchus* larvæ develop in the marshes along the coast, and are often associated with the larvæ of *Anopheles costalis*, *C. univittatus* and *C. thalassius*. The larvæ have long slender siphons, and their bodies are often striped. To the unaided eye they thus resemble the larvæ of *C. univittatus* closely, but

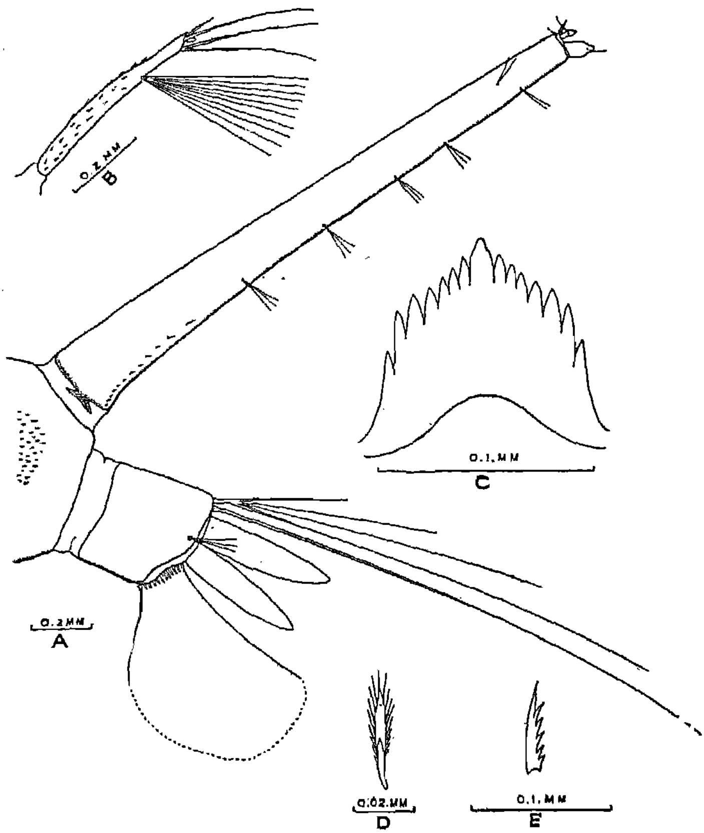


FIG. 38

SIPHON OF *Culex tritæniorhynchus*, Giles

(After P. J. Barraud: "A Revision of the Culicine Mosquitoes of India")

they may at once be distinguished from the larvæ of *C. univittatus* by the fact that the siphon (*Fig.* 38, *page* 166) usually carries six pairs of hair-tufts composed of from two to five short hairs, arranged as stated in the key-table on *page* 153. The species is extremely common in many parts of Mauritius, but its distribution seems mainly confined to the coastal belt.

Culex sitiens, Wiedemann

As it is doubtful whether this species occurs in Mauritius, further investigation is needed to settle the question.

Culex sitiens belongs to the marsh-breeding group of *Culex* mosquitoes, having yellow-banded proboscides.

Wiedemann describes the species as follows: "Tarsi dark brown, with narrow basal bands on the three or four upper joints of the fore and mid legs, *but with the hind tarsi unbanded.* Thorax dark brown, with scattered golden scales, paler in the middle, but not noticeably marked. Abdominal segments deep brown, with narrow ochreous basal bands, except the first, which has a dark brown patch in the centre. Proboscis deep brown, with a narrow yellow band well outside the middle. Head brown, with creamy curved and numerous black forked scales; palpi (in the female) short, thick, dark brown, greyish at the top. Pleuræ dark brown, with a white patch under the wings and another over the middle pair of legs. Legs dark brown, except the greyish-yellow undersides of the femora, which are armed with a distinct row of strong bristles. Halteres with pale stems and fuscous knobs. Length, about three millimetres."

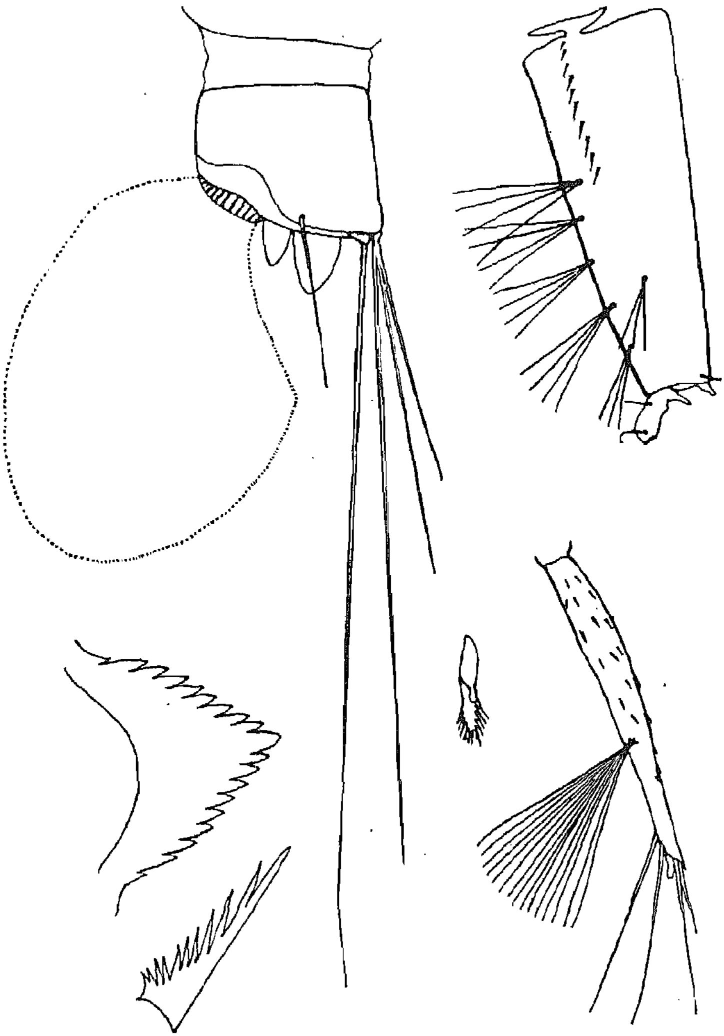


Fig. 39

The Siphon, Antenna and Anatomy of Terminal Abdominal Segment of *Culex sitiens*, Wiedemann

(After P. J. Barraud: "A Revision of the Culicine Mosquitoes of India")

The Larvæ. The larvæ of *Culex sitiens* will be easily recognised from the other Mauritian and Rodrigian species of *Culex* by the fact that the siphon is short and broad, and carries six pairs of large hair-tufts arranged as indicated in *Fig.* 39, *page* 168.

My chief reason for thinking that *Culex sitiens* occurs in Mauritius is that once, in February, 1923, when the larvæ met with an accident and were lost, and again within two days of my departure from the Island, a number of larvæ were captured from a brackish drain (Roche Bois), and, though they resembled the larvæ of *C. thalassius* in some ways, the larvæ themselves and their siphons were shorter, and the distribution of the hair-tufts on the siphon was somewhat different. As I mention on *page* 147, former records had led us to believe that we had already obtained *C. sitiens* larvæ in the long-siphoned larvæ which were ultimately found to be those of *C. tritæniorhynchus*. Consequently, I recorded this species (*Le Cerńeen*, February 28, 1923) under the record number R.N. 40, and when the larvæ were again found, shortly before my departure from Mauritius, there was then no apparatus available with which to make additional studies of these specimens. After my return to England, Mr. F. W. Edwards kindly lent me a mounted larval specimen of a definitely identified *C. sitiens*, and although no similar larvæ are in my Mauritian collections, the Roche Bois larvæ are, unfortunately, not represented. Nevertheless, I am fairly certain that Mr. Edwards' *C. sitiens* larva and the larvæ caught at Roche Bois are identical, and therefore it seems probable the presence of *C. sitiens* in Mauritius will ultimately be established. In my "Report on the Anophelinæ of Mauritius," the record "18. *Culex univittatus*, *var.* Roche Bois, MacGregor (R.N. 40)" refers to

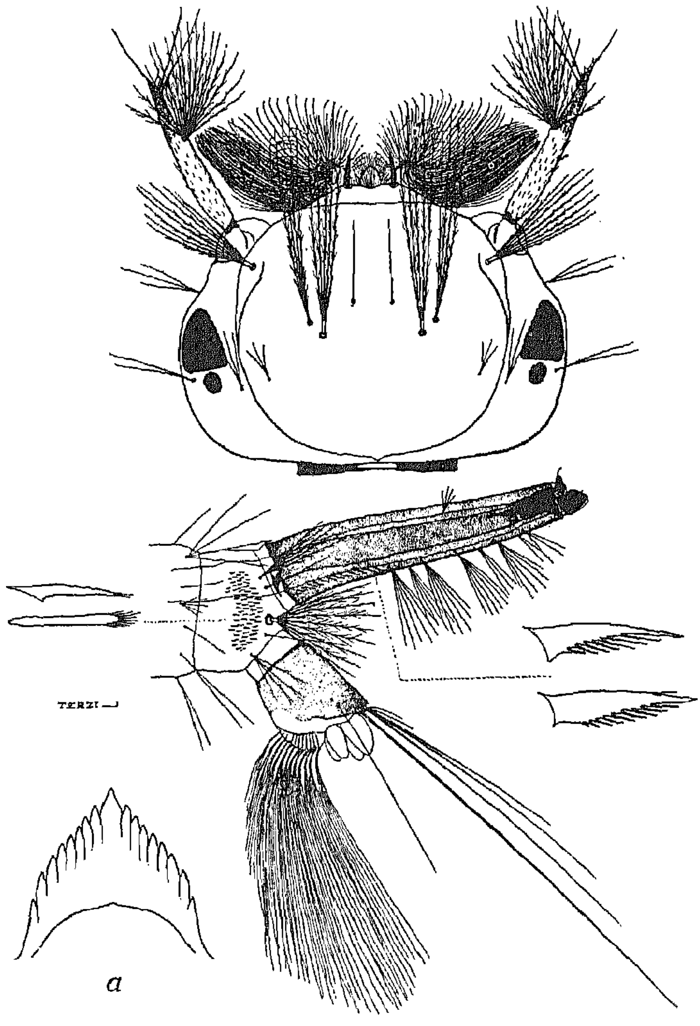


FIG. 40

LARVA OF *Culex thalassius*, Theobald

Head and end of abdomen; *a*, mental plate. (After Ingram and Macfie)

the Roche Bois larvæ. The word *univittatus, var.*, there used, is a mistake due to entanglement with previous records which had not then received the study that has subsequently been found necessary.

Culex thalassius, Theobald

Description and Bionomics

C. thalassius is a large and fairly common species in Mauritius, along the coastal belt, where it, too, breeds in the marshes, often in association with *Anopheles costalis*, *C. tritæniorhynchus*, *C. univittatus*, and sometimes with *C. fatigans*. In the adult stage it is in some characters rather like *C. tritæniorhynchus*, but its larger size, the position of the band on the proboscis, and the mixture of pale and dark scales on the dorsal surface of the thorax, clearly distinguishes *C. thalassius* from *C. tritæniorhynchus*. The following are the most conspicuous specific characters: Proboscis with a broad band of yellowish scales at its middle; articulations of all the leg joints with narrow pale bands; dorsal surface of the thorax clad with a mixture of dark brown, light brown and golden yellow scales; palpi of the males banded at the articulations; palpi of the females unbanded, but with a few white scales at the tips.

C. thalassius seems to prefer marshes in which the water is shallow, and somewhat foul through the decomposition of vegetable material. It is, however, frequently found in clear marsh-water pools, but in such situations the larvæ are never as numerous as they often are in foul marsh pools. The species seems to be confined in Mauritius to the coastal marshes, and it was not found in the inland districts at any time during my investigations in the Island.

The Larvæ. *Culex thalassius* larvæ are easily distinguished from those of *C. univittatus* and *C. tritæniorhynchus* by the fact that the siphon in *C. thalassius* is neither as long nor as slender, and is equipped with large siphonal hair-tufts. The siphonal hair-tufts number six, five pairs being arranged on the siphon ventrally, while the sixth pair is laterally placed on the siphon at a point between the fourth and fifth ventral pairs. *C. thalassius* larvæ are distinguished from the larvæ of *C. sitiens*—in which the arrangements of the siphonal hair-tufts is rather similar—by the fact that the siphon of the latter species is quite short. In *C. thalassius*, the dimensions of the siphon are: Length 6 to 7 times the breadth at the base, whereas in *C. sitiens* the length of the siphon is only 2 to 2½ times the breadth at the base (*Fig.* 40, *page* 170).

Culex quasigelidus, Theobald

Description and Bionomics

This interesting and ornamented species is fairly common in Mauritius. It is, to some extent, a marsh-breeder, but it is more often found in the backwaters of rivers where the water is clear and contains a large amount of living grass or slender water-weeds.

Culex quasigelidus is a large rather light-brown species, which is very easily identified by its conspicuous ornamentation. Proboscis, with a broad yellow band at its middle; male palpi with five yellow bands, and the apices of the palpi yellow; female palpi, one narrow yellow band, and

apices of the palpi yellow; all the articulations of the leg joints, except the articulations of the 5th metatarsi, clearly marked with narrow yellow bands; femora and tibiæ of all the legs, evenly speckled with yellowish-white dots; thorax with a broad band of golden-yellow scales across its middle, and an unusually large number of long black hairs; remainder of the scales on the thorax, dark brown and reddish-brown.

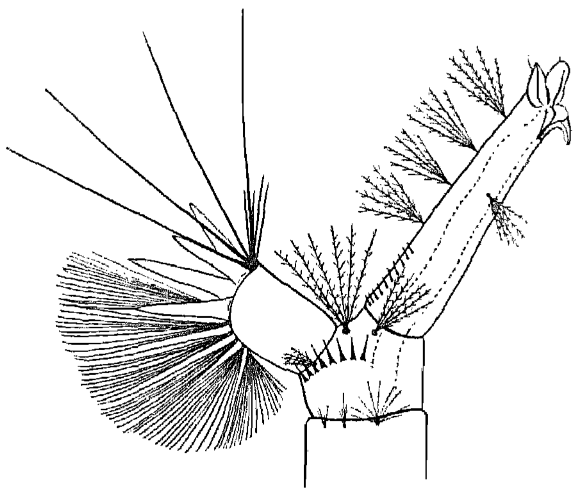


FIG. 41

SIPHON OF *Culex quasigelidus*, Theobald

The Larvæ. The larvæ of *Culex quasigelidus* are identified as easily as the adult. The siphon is about five times as long as its breadth at the base, and carries five pairs of plumed hair-tufts. Four of the pairs of hair-tufts are situated ventrally, while the fifth pair is smaller and is situated dorsally almost opposite the second ventral pair. The valves of the siphon are more than usually large (*Fig.* 41, *above*). Tips of the antennæ dark,

middle portion conspicuously white. Unlike the other Mauritian larvæ of the Genus *Culex,* the larvæ of *C. quasigelidus* will, at times, adopt a sub-aquatic method of respiration, and probably the enlargement of the siphon valves in this species is correlated with this method.

The sub-aquatic method of respiration may be witnessed in situations where there is much submerged living vegetation, while the water-surface is exposed to direct sunlight. Under such conditions, transpiration of the plants is vigorous, and the submerged stems and leaves are often studded with adherent bubbles of oxygen. The *C. quasigelidus* larvæ then leave the surface and attach themselves by the tips of their siphons to the adherent gas bubbles, where, from two to four feet below the surface, they remain motionless, except for the action of their mouth-brushes, quietly feeding often for hours on end. Thus, in searching for *C. quasigelidus* larvæ, sometimes they are easily captured in large numbers simply by sweeping the breeding-places with " dippers " in the ordinary way, but if the breeding-place is in direct sunlight, the weeds should be first thoroughly stirred with a long stick before the " dippers " are brought into use. If frightened in this way, the larvæ will always be found to come to the surface a few minutes later.

Culex rima, Theobald

Description and Bionomics

Although this species may be also classed as a " wild " species, in Mauritius, as far as we know, it only breeds in particular types of breeding-place—rock-holes and holes in the ground along river courses. *Culex rima* is a rather small dark species. The dorsal surface of the thorax

is clad with reddish-brown scales, but the legs and abdomen are almost black. There are no markings on the legs, and the tibiæ and tarsi are uniformly dark ; femora dark on dorsal surface, pale on ventral surface. Abdomen deep brownish-black with narrow white bands situated on the *apical* portion of each segment. Thorax, dorsal surface reddish ; pleuræ marked with horizontal dark lines.

Culex rima is not a very common mosquito in Mauritius, although, on the other hand, it cannot be said to be rare. It seems to have a wider distribution than that of *C. univittatus*, *C. tritæniorhynchus*, *C. thalassius* and *C. quasigelidus*, as its larvæ were several times found in localities near the coast, and also occasionally larvæ were collected in considerable numbers at Reduit, Beau Bassin and elsewhere. The adults were seen only once in the wild state. On this occasion the larvæ were being collected from a hole in the ground on the course of Riviere des Calebasses, in the District of Calebasses, when a few adults were observed to feed on the collectors. These mosquitoes were not very persistent in their attack, and were readily drive off. No adults were ever found in houses.

The Larvæ. The larvæ of *Culex rima* are noteworthy on account of their remarkably long and slender siphons. The body-colour is generally of a neutral tint, the lighter portions being transparent, while the opaque portions are dark. The siphon carries five pairs of very small hair-tufts disposed on the ventral surface. The space between the succeeding hair-tufts increases between each pair from base to apex. A good light, and fairly high magnification, under the microscope, are essential if these hair-tufts are to be observed, but in many larvæ the hair-tufts are often absent.

Nevertheless, the general form of the siphon, the pecten of from 10 to 11 teeth, and the large number of teeth composing the comb, are more than sufficient characters for the identification of *C. rima* larvæ (*Fig.* 42, *below*). Larvæ were only

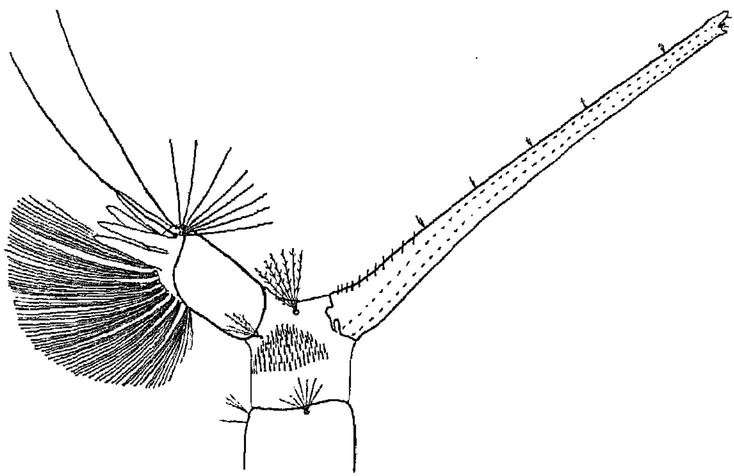


FIG. 42

SIPHON OF *Culex rima*, Theobald

found in shady situations, in holes in the ground under trees near rivers, in shaded river pools, in rock-holes close to the main course of rivers, and occasionally in shaded ponds. The larvæ seem to prefer water that is quite foul with decomposed vegetation, and at times *C. rima* larvæ were found in association with the larvæ of *Aëdes albopictus* and *Lutzia tigripes*.

Culex simpsoni, Theobald

Description and Bionomics

This species was found in Rodriguez, and apparently does not occur in Mauritius. It is an extremely common species in the former Island, at least along the coast. Inland it is not quite so numerous, but several specimens were captured at an altitude of 900 feet during our investigations in Rodriguez. *C. simpsoni* is a highly ornamented species, and is easily recognised by the unaided eye. Thorax dark brown, ornamented with shining golden-yellow scales, yellow-white scales, and long brown and yellow hairs. The golden-yellow and yellow-white scales form a distinct pattern : there is a broad longitudinal band of golden-yellow scales along the median line of the thorax, extending to about its middle; on each side of this median line of yellow scales there is a roughly bow-shaped patch of similar scales, while from the median posterior margin of the thorax a short band of yellow-white scales runs forward for about one-third of the total length of the thorax. The pattern formed by these lines might aptly be described as a " lyre-shaped " design. Pleuræ with conspicuous patches of white scales. Palpi of the male: the two terminal (3rd and 4th) joints dark, but ornamented on their ventral aspects with numerous white scales; 2nd joints paler, with a narrow yellowish band before the middle point. Palpi of the female dark, with numerous white scales on the dorsal aspects of the terminal segments. Proboscis of the male dark brown, with a narrow yellow band a little beyond the middle point. Proboscis of the female yellow for two-thirds of its length from the base, with the remaining apical third dark.

Abdomen in both sexes, chocolate-brown, with broad basal bands of white scales on each of the segments. Legs: tibiæ and tarsi black; narrow yellow bands on the articulations of the tibiæ and femora only; femora black and yellow, the yellow colour predominating, especially in the hind pair of legs, in which the basal two-thirds are entirely yellow.

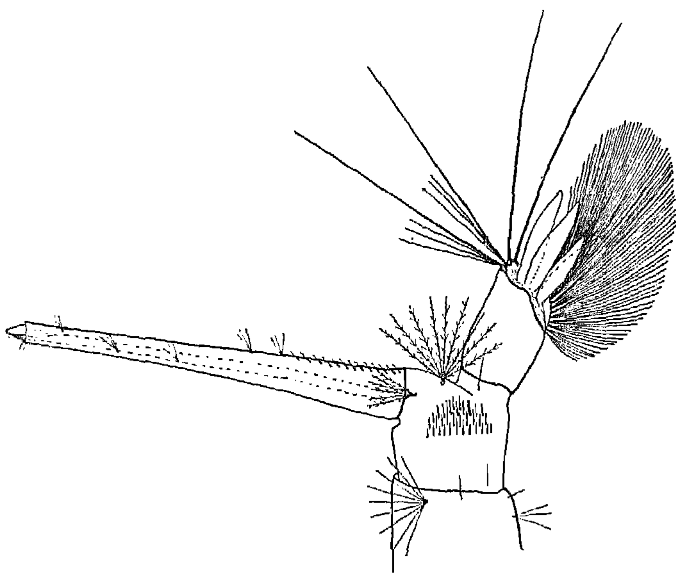


FIG. 43
SIPHON OF *Culex simpsoni*, Theobald

The Larvæ. The larvæ of *Culex simpsoni* have fairly long and very slender siphons. The body-colour is often greenish, and the larvæ were found to occur in their breeding-places in astonishingly large numbers, even in rivulets and ponds of considerable extent, literally hundreds of larvæ frequently being collected by a single "dip." The siphon carries five pairs of small or minute hair-tufts, which are fairly equally spaced, but in

an unusual arrangement: the first two pairs are situated ventrally, the second two pairs dorso-laterally, while the fifth and terminal pair has also a ventral position, thus giving an alternate arrangement of the siphonal hair-tufts. It should be pointed out, however, as in the case of the other larvæ with small siphonal hair-tufts, that any or all of these hair-tufts are not infrequently absent in some specimens. The pecten is composed of from 11 to 13 rather long and somewhat widely spaced teeth, and the comb is a triangular patch, comprising from 30 to 35 teeth. Anal gills of moderate length; dorsal pair larger and longer than the ventral pair (*Fig.* 48, *page* 178).

Culex simpsoni larvæ in Rodriguez were very often found to occur in association with the larvæ of *C. fatigans*, and there can be little doubt that although *C. simpsoni* was found to breed only in natural waters, the species readily bites human beings, and with *C. fatigans* is equally responsible for the severe discomfort caused to the inhabitants of the Island by mosquitoes.

Notes on the Species of the Genus Culex in Mauritius and Rodriguez

There is unquestionably considerably more difficulty in the identification of the different species of *Culex* than is the case with the species of the other genera, but, nevertheless, the mere fact that greater care and observation are demanded on the part of the investigator adds zest to the work of identification. Fortunately, all the species in Mauritius and Rodriguez have well-defined specific characters, even though at first some of the different species may appear remarkably alike, and ultimately, after experience has been gained, the investigator will find that he is

able to recognise all species instantly by that peculiar faculty of the mind whereby familiar composite impressions are alone sufficient for immediate recognition. From my own experience in Mauritius, during a stay of about 10 months, it seems likely that of the *Culex* species only one, *i.e.*, *Culex fatigans*, is of any importance from a Public Health standpoint. It is very probable that the other species usually devote themselves to animal and bird hosts, and rarely attack man. In only a single instance (*page* 175) were any of my staff or myself ever bitten, as far as we know, by a *Culex* other than *C. fatigans*, even in the localities where the remaining species are numerous. Possibly the explanation of this fact may rest on the likelihood that in common with *C. fatigans* the other species only feed at night. If that is so, the species, nevertheless, are to be regarded as being unimportant, as they are "wild" and do not often enter houses.

In Rodriguez, on the other hand, we have two species, *Culex fatigans* and *Culex simpsoni*, which breed in very large numbers near human habitations. My stay in Rodriguez was necessarily very short, and with my attention occupied most of the time on other matters, I was only able to form a cursory impression about the activities of *C. simpsoni*. However, as several adults were caught at night while I was inspecting the cable-relay instruments in the transmitting rooms of the Eastern Telegraph Company, and the cable operators complained bitterly of the annoyance caused by the mosquitoes, it seems probable—although *C. fatigans* was also present in large numbers—that *C. simpsoni* in Rodriguez is to be regarded as a serious pest. This is emphasised by the fact that the larvæ of *C. simpsoni* were to be found in prodigious numbers in almost every natural and artificial water around Port Mathurin,

and a food supply sufficient for the generation of such hosts of larvæ is not likely to be represented by anything other than human blood.

In this connection, it is well to keep in mind, the added misfortune that might accrue to Mauritius if *C. simpsoni* were accidentally imported, for, in my long experience with mosquitoes, I have never encountered a comparably intensive breeding to that of *C. simpsoni* in Rodriguez. Were *C. simpsoni* to succeed in establishing itself in Mauritius, it is not improbable that the already almost intolerable mosquito nuisance in the coastal towns would be increased by 100 per cent.

An interesting and rather remarkable phenomenon in regard to some of the species of *Culex* in Mauritius is the striking periodic appearance and disappearance of certain species. Thus, in most of the marshes of the Black River and Port Louis Districts, where this phenomenon was studied, *C. univittatus* was at times obtainable almost " in pure culture." Gradually, in the course of several weeks, the number of the larvæ would decline, the larvæ of *C. thalassius*, *C. tritæniorhynchus* and *Anopheles costalis* reveal themselves in association with the remaining *C. univittatus* larvæ, until progressively the latter larvæ temporarily completely disappeared from the marsh. Then dominance would be established by one of the other species until its numbers in turn declined and the ascendancy was gained by yet another species. Usually, in the end, *A. costalis* would have the water of the marshes to itself for a time and later the cycle would ensue again. This cyclic alternation was not altogether a seasonal phenomenon, for it was found to occur several times during the spring, summer and autumn months, with a lack of regular precedence in the ascendancy of the separate species. The only fact which could be established was that *C. univittatus* would invariably be found

a few weeks after the copious irrigation of the sugar-cane plantations on the highlands had added to the water of the marshes by natural drainage. It therefore seems most likely that changes in the composition of the water, rather than seasonal influences, were at work.

EDWARDS' KEY TO THE GENERA OF THE TRIBE CULICINI

In the future it is not improbable that mosquitoes of other genera may be found to have made their way into Mauritius and Rodriguez. Moreover, workers in other parts of the world are likely at all times to discover genera not hitherto recorded from their particular localities. Mr. F. W. Edwards, of the British Museum of Natural History, in London, has recently (1922) published a most valuable key to the known genera of the Tribe *Culicini*, and I am indebted to him for his permission for its republication here. In regard to the Tribe *Anophelini*, the key to the single genus and the five sub-genera has already been given (*pages* 98 *and* 99), and workers in all regions are thus well equipped for the study of mosquitoes.

In the course of the subject matter of this little book the method of using the identification keys will, I think, have become apparent to the reader. If not, the following is a brief indication of the correct method of using these keys.

We will assume that two culicine mosquitoes, A and B respectively, are to be assigned to their correct genera by the use of Edwards' generic key. By examining each mosquito in turn under the binocular microscope, both the mosquitoes, let us say, are found not to possess the generic characters given under the first section of Division 1 of the table. Neither, therefore, belongs to the Genus

Megarhinus. We pass, therefore, to Division 2. Examining the mosquitoes again and reading the characters given in Division 2, let us assume that mosquito A is found to possess the characters recorded in the first section, while the characters of mosquito B conform to those given in the second section of the same Division—Division 2. Turning our attention for the time exclusively to mosquito A, we find at the end of the first section of Division 2 there is the figure 3, which indicates that all mosquitoes with such characters must now be referred to Division 3. If the characters of the mosquito are found not to conform to those given in the first section of Division 3, we pass to the second section of the same division, and subsequently to Division 4, and so on. In this case it is obvious that mosquito A will be found to agree with the generic characters given under one of the Divisions between 3-6, and the mosquito belongs to that particular genus.

Returning now to the further consideration of mosquito B. We have already found that its characters conform to those recorded in the second section of Division 2, at the end of which is the figure 7. We pass, therefore, direct to Division 7. Let us assume that its characters do not conform to those of the first section of Division 7, but are found to agree with the characters of the second section. At the end of this section we find the figure 16. We pass directly to Division 16, where we are referred either to Division 17 or to Division 34, as the case may be. If " pulvilli present " is true for our mosquito, we again, therefore, pass directly to Division 34, and our mosquito must clearly then belong either to the Genus *Lutzia*, *Deinocerites*, *Carrollia*, or *Culex*.

It should be noted, in first using the majority of identification keys, that if a mosquito agrees with the *first* of any two reference numbers—such, for

example, as 17 and 34—the particular genus to which the mosquito will ultimately be found to belong will occur somewhere between these two numbers.

Once the correct genus of a mosquito has been established, as the number of described species is now so numerous, workers should, for the specific identification, adopt the policy of utilising the keys contained in most of the publications on local mosquito records, or, alternatively, send specimens of the mosquitoes to one of the recognised systematic authorities.

In regard to the specific determination of the Anophelini, Christopher's "Provisional List and Reference Catalogue of the Anophelini" (Ind. Med. Res. Memoirs, No. 3, Thacker & Spink, Calcutta) is an invaluable publication.

Edwards' Key to the Genera of the Culicini

1. Clypeus broader than long, flat; proboscis rigid, stout on about the basal half, apical half much more slender and bent backwards; scutellum with the posterior margin evenly rounded; cross-vein r-m bent at right angles, one part of it being horizontal; a V-shaped thickening of the wing-membrane on the margin between the forks of C_u .... *Megarhinus.*

   Clypeus longer than broad, convex; proboscis flexible, its outer half not more slender than the basal; scutellum more or less distinctly trilobed; cross-vein r-m straight, vertical; wing membrane without V-shaped thickening 2

2. Base of vein R_s, base of fork of C_u, and apex of A_n very nearly in a line at right angles to the costa, the tip of A_n ending slightly before, under, or only very slightly beyond the base of the fork of C_u 3

   Base of R_s considerably before the base of the fork of C_u, which again is considerably before the tip of A_n (in other words, the line joining these three points makes a very acute angle with the costa) 7

3. Wing-membrane without microtrichia; sternopleural bristles well-developed; cell R_2 much shorter than its stem .... *Uranotænia.*

Wing-membrane with distinct microtrichia, visible under a magnification of 50 as dark dots; sternopleural bristles absent, or small and weak...... 4

4. Labella greatly enlarged, and provided with four very long hairs; clypeus unusually long and narrow *Harpagomyia.*

Labella normal, neither enlarged nor with long hairs; clypeus not unusually long 5

5. A row of four or five pro-epimeral bristles; cell R_2 shorter than its stem .... *Zeugnomyia.*

Only two pro-epimeral bristles; cell R_2 longer than its stem 6

6. Pro-epimeral bristles long; no spiracular bristles; wing-scales emarginate at their tips .... *Hodgesia.*

Pro-epimeral bristles very short; one or two small spiracular bristles present; tips of wing-scales not emarginate .... *Topomyia* (part).

7. Pleural bristles reduced; upper sternopleural absent; not more than two pro-epimeral; on the other hand, at least one or two spiracular are nearly always present 8

Pleural bristles less reduced; either the upper sterno-pleural or several pro-epimeral present...... 16

8. Postnotum without setæ; row of orbital bristles incomplete; Oriental and Australasian genera 9

Postnotum with a well-marked tuft of setæ; a row of small orbital bristles present; American genera...... 11

9. Clypeus rather long; head with a spot of metallic silver scales in front; proboscis not longer than the abdomen *Topomyia.*

Clypeus rather short; head without metallic silver scales in front 10

10. Proboscis shorter than the abdomen, which is not laterally compressed .... *Rachisoura.*

Proboscis longer than the abdomen, generally longer than the whole body; abdomen laterally compressed *Rachionotomyia.*

11. Eyes separated by at least a narrow area ; pro-thoracic lobes collar-like 12

Eyes broadly contiguous above ; pro-thoracic lobes sub-lateral 15

12. Pro-thoracic lobes contiguous or closely approximated dorsally 13

Pro-thoracic lobes well separated 14

13. Front femora shorter than the middle ones ; middle tibiæ and tarsi with fringes of long scales ...... *Sabethes.*

Front femora as long as the middle ones ; middle tibiæ and tarsi without long fringes .... *Sabethoides.*

14. Hind tarsi with two claws ; small spiracular bristles present (always ?) .... *Wyeomyia.*

Hind tarsi with but a single claw ; spiracular bristles absent, but the area densely scaly ....*Limatus.*

15. Clypeus with setæ...... ....*Trichoprosopon.*

Clypeus without setæ, at most with a microscopic pubescence .... *Goeldia.*

16. Pulvilli absent 17

Pulvilli present 34

17. Prescutellar bristles absent ; pronotal lobes often large, their bristles arranged in a row on the front margin ; mesonotal scales straight and more or less metallic 18

Prescutellar bristles present ; pronotal lobes generally small, their bristles irregularly arranged ; mesonotal scales mostly curved and not metallic 19

18. Postnotum with a well-marked tuft of setæ *Heizmannia.*

Postnotum bare, or at most with two or three minute setæ .... *Hæmagogus.*

19. Postspiracular bristles present 20

Postspiracular bristles absent 27

20. Spiracular bristles present (few and small in sub-genus *Janthinosoma*) .... *Psorophora.*

Spiracular bristles absent...... 21

21. Cross-veins clouded, m-cu slightly outside r-m...... 22
Cross-veins clear, m-cu well inside r-m(except in individual aberrations) 23

22. About 20 pro-epimeral bristles ....*Mucidus.*
About five pro-epimeral bristles ...... *Pardomyia.*

23. Eyes widely separated, the space between them clothed with silvery scales; abdomen laterally compressed *Eretmopodites.*
Eyes rather narrowly separated or even touching, the space between them not silvery-scaled...... 24

24. Wing-scales generally mostly narrow (when, rarely, all are broad, the ♀ claws are toothed) 25
Wing-scales all very broad; ♀ claws simple *Tæniorhynchus* (part).

25. Proboscis rather stout, more or less re-curved in repose 26
Proboscis rather slender, seldom re-curved in repose *Aëdes.*

26. Antennæ unusually stout, and short-haired (♂ ♀); head with many scattered short bristles...... ...... *Opifex.*
Antennæ normal; head with vertical and orbital bristles only .... *Armigeres.*

27. Spiracular bristles present .... *Theobaldia.*
Spiracular bristles absent...... 28

28. Last two antennal joints short and broad (♂ ♀) *Aëdomyia.*
Last two antennal joints long and slender (♂ ♀) 29

29. First joint of front tarsi distinctly longer than the last four together; fourth very short; only two strong pro-epimeral bristles .... *Orthopodomyia.*
First joint of front tarsi not longer than the last four together; fourth not, or scarcely, shorter than the fifth (♀); several strong pro-epimeral bristles 30

30. Proboscis rather stout and curved backwards somewhat in repose; mesonotum more or less produced over the head; postspiracular area scaly *Armigeres*, sub-genus *Leicesteria.*
Proboscis not curved backwards in repose; mesonotum not produced over the head; post spiracular area bare 31

31. Cell R_2 shorter than its stem (compare also *Zeugnomyia*, which would run down here if included under the second part of heading 2) .... *Mimomyia*.

Cell R_2 not shorter than its stem...... 32

32. Proboscis swollen at the tip (greatly in ♂, slightly in ♀) *Ficalbia*.

Proboscis not swollen at the tip 33

33. First hind tarsal joint shorter than the tibia; empodia normal ...... *Tæniorhynchus*, sub-genus *Coquillettidia*.

First hind tarsal joint as long as the tibia; empodia chitinised and plate-like (?) .... *Climacura*.

34. Lower mesepimeral bristles numerous .... *Lutzia*.

At most three lower mesepimeral bristles, usually one or none 35

35. First flagellar joint at least twice as long as the second (♂ ♀) *Deinocerites* (including *Dinanamesus* and *Dinomimetes*).

First flagellar joint scarcely, if any, longer than the second 36

36. Abdomen compressed laterally; sternopleural bristles few in number and not forming a continuous row *Carrollia*.

Abdomen not compressed laterally; sternopleural bristles in a continuous row .... *Culex*.

♂ = conventional sign denoting *male*

♀ = ,, ,, ,, *female*

PART III

LABORATORY AND FIELD TECHNIQUE

Laboratory Technique. In the study of mosquitoes more than half the work is necessarily undertaken in the laboratory. It is there, with the aid of the microscope, that the definite identification of any particular species of adult pupa or larva is confirmed; it is in the laboratory that the mounting processes of all the mosquito developmental stages are performed; it is in the laboratory, almost entirely, that the development of mosquito-borne diseases is studied; and only in the laboratory, or in an associated "breeding-room," can the breeding and rearing of mosquitoes be carried out under close observation. Nevertheless, it is the field investigations which give purpose to the work of the laboratory, and neither side can be fully understood or be worked to the best advantage without the other. Laboratory work without contemplation of field conditions is apt rapidly to degenerate into a labour of mere routine collection and cataloguing, and field work pursued without the guidance of laboratory observations is almost certain speedily to go very far wrong and become extravagant.

Although the importance of the laboratory in mosquito investigations is so great, fortunately the necessary equipment for satisfactory work is simple. The following items are the chief requirements :—

Microscopes. Nowadays, at least one binocular entomological microscope is absolutely indispensable. This instrument should be equipped

with a full range of objectives and paired eye-pieces. Also, at least one ordinary compound microscope should be provided, equipped with mechanical-stage, sub-stage condenser, several eye-pieces and a full range of objectives, including a 1/12″ oil immersion. The necessary accessories are, a microscope-lamp—a good acetylene bicycle-lamp is an excellent makeshift when nothing better is available—an eye-piece and stage-micrometer; a large bull's-eye condenser with universal joints; and a most useful additional accessory is some good form of camera lucida.

Insect Storage and Slide Cabinets. The adult insects, mounted on celluloid stages, are preferably stored in the special entomological cabinets with glass-topped drawers, which are obtainable in all forms and sizes from the various supply houses. Failing this, the adult insects may be kept satisfactorily in the ordinary entomological storage boxes, and for the purpose the 15″ by 18″ size is the most convenient. Other sizes will also be necessary for the temporary housing of the insects and in the preparation of subsidiary collections, etc. For these purposes, the 10″ by 8″ and the 6″ by 3″ sizes are most useful.

Naphthalene, which is so often used in entomological storage-boxes to preserve the contained specimens from the destructive attentions of other insects, fulfils this function fairly well in temperate climates, but in hot weather, and particularly in the Tropics, naphthalene volatises so rapidly that it needs to be frequently renewed. In addition, it has little or no control over the growth on the specimens of fungi which in the Tropics are often more destructive to collections than even the small insect pests. Creosote, in place of naphthalene, admirably safeguards the collections both from fungi and these insect pests. As creosote is a

liquid, however, its application to the storage-boxes has involved difficulties. Special safety-bottles are made, which may be placed in the storage-boxes, but they are often difficult to obtain, and the common types are somewhat cumbersome. Pieces of cotton wool are sometimes pinned in the boxes, and a few drops of creosote poured on the wool, but this is a most unsatisfactory method, as the creosote spreads on to the inner surface of the box and causes a very untidy appearance. Neat and thoroughly serviceable creosote bottles can be made without difficulty from glass tubing, and if they are pinned into one corner of the boxes, these bottles take up very little room. Moreover, owing to their design, no matter in what position the box is held or placed, they cannot spill their contents. These bottles are made in the following way (*Fig.* 44, *page* 192).

Obtain a piece of glass tubing about $\frac{1}{8}''$ in internal diameter. Seal one end by revolving it in the flame of a blow-lamp, and then, when the lumen has been completely closed, heat the glass to a bright red colour, and, by blowing carefully down the open end of the tube, form a spherical bulb about $\frac{1}{2}''$ in diameter. Allow the glass to cool and transfer the glass tube with the bulb at one end to the left hand. In the right hand take a mounted dissecting-needle and bring the upper surface of the bulb into the flame once more until the glass softens. Then remove the bulb from the flame and rapidly, but with a steady pressure, strike the softened glass at the centre with the point of the needle, and press the glass inwards until the point of the needle reaches to the centre of the sphere. This results in the formation of a semi-spherical bulb with an invaginated centre, similar to the familiar safety ink-pot.

Allow the glass to cool, and with the needle carefully break through the glass at the middle of

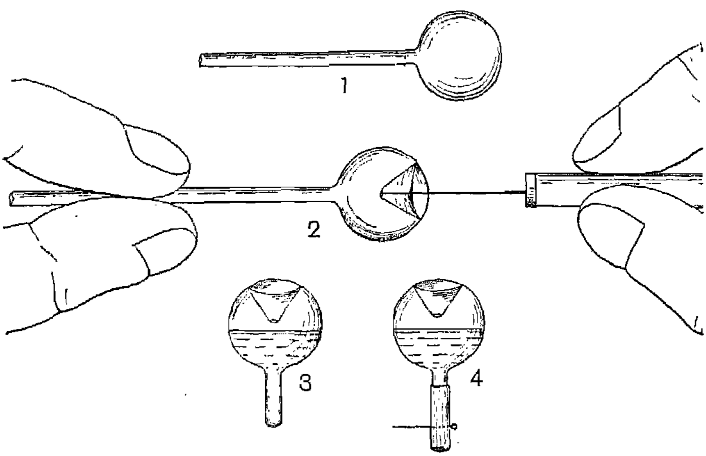


FIG. 44

METHOD OF CONSTRUCTION OF SPECIAL CREOSOTE-BOTTLES

1. Glass tubing with bulb blown on one end; 2. depressing the softened upper surface of the bulb; 3. the bulb cut off from the tube and filled with creosote; 4. rubber tubing and pin attached ready for inserting into specimen box.

the depressed centre, forming a hole about 1/16″ in diameter. Now cut off the bulb from the glass tubing, leaving about an inch of the tube attached to the lower end of the bulb, and seal this end of the tube by revolving it in a flame. Over the sealed end of the tube, a small piece of rubber tubing is slipped, leaving ¼″ of the rubber tubing extending beyond the sealed end of the glass. Half fill the bottle with creosote by means of a capillary pipette, whose end will enter the hole in the centre of the bulb, and the bottle, lying on its side, may then be pinned through the rubber into one corner of the box.

These bottles have been found to act splendidly ; the creosote evaporates rapidly enough to preserve the specimens perfectly, although one charge of the creosote will last for more than a year.

The slide cabinet should be one sufficiently large to hold at least 500 microscopical slides, and, in addition, several slide-storage boxes of the slot variety will be required.

Microtome. If available, any good make of microtome will often be found a very valuable instrument in the laboratory. It will naturally be furnished with the necessary accessories, such as the knives, embedding apparatus, etc.

The Turn-table. As this apparatus will be in constant use in the mounting of larvæ, etc., it is advisable to have only an accurately-constructed instrument, and one provided with a fairly heavy, concentrically-ruled revolving table.

Entomological Mounting Pins. Only two different sizes are needed, namely No. 2 and No. 19, white (Kirby, Beard & Co., London), or No. 11 and No. 20, white (D. F. Taylor & Co., Birmingham). The former in each case is the

heavier supporting-pin, and the latter the fine stage-pin on which the insect is mounted. Both pins should invariably be of the " white " variety.

Staging. Unquestionably the best material for stages is sheet celluloid. It is transparent, hard in any climate, and now readily obtainable almost everywhere, as it is largely used for motor-car side-screens and the repair of celluloid accumulator cases.

Tin Cells. These are circular rings of pure tin, and are used to form cell-slides for mounting large objects, such as larvæ, pupæ, etc. Two sizes are required, namely rings with $\frac{5}{8}''$, and others with $\frac{7}{8}''$ external diameters. The thickness of the rings should be about $\frac{1}{8}''$. Twice as many of the former size as of the latter will be used.

Cover Glasses. To complete the construction of the cell-slides, circular cover-slips of the same diameters as the tin-rings are required. A supply of $\frac{5}{8}''$ No. 2, and $\frac{7}{8}''$ No. 2 must therefore be provided.

Reagents. The ordinary list of biological laboratory reagents will be useful, but there are also the following reagents, whose presence in the laboratory must be assured :—

Pale gold-size.
Black asphalt varnish.
Creosote.
Formaldehyde, 40 %.
Chloroform.
Ether.
Cedar-wood oil.
Turpentine.
Glycerine.
Acetic acid.
Silver nitrate.
Sodium hydroxide.
Borax.

STAINS.

Water-soluble eosin.
Alcohol-soluble eosin.
Methylene blue.
Haemalum.
Borax carmine.
Fuchsine.
Gentian violet.
Leishman's Romanowsky.
B.D.H. Universal Indicator.

Important small items. Entomological collecting-bags, fitted with pockets to carry tubes in an upright position ; pin-forceps ; dissecting-needles (preferably of metal, and fitted with small " chuck " needle-holders) ; scalpels ; scissors ; carborundum, or other sharpening-stone for needles and scalpels ; a small paraffin or petrol blow-lamp for glass-blowing, etc. ; grease-pencils for writing on glass ; fine sable-hair paint brushes, size No. 0 and No. 00 (for cell-slide making) ; glass tubing of various diameters up to half-an-inch external diameter ; glass files ; good quality thick-walled (not " pressure ") rubber-tubing ; plenty of large and small white filter-papers; several large rubber aural syringe-bulbs—or, failing this, motor-car horn bulbs will do ; a pair of " tin-man's " metal shears ; a small soldering outfit; mosquito netting (18 mesh to the inch); good quality cheese-cloth ; at least one gross of glass flat-bottomed specimen tubes, 3″ long by 1″ in diameter, and one gross of similar tubes, 4″ by $1\frac{1}{4}$″, with corks to fit ; at least two dozen plain glass dessert finger-bowls ; linen-thread and sewing needles ; entomological cork slabs ; one gross of Wassermann reaction tubes ; map-marking pins with coloured heads (assorted colours).

Card-index Files and Loose-leaf Note-books. The most useful size of card-index file-card for entomological records is perhaps 5″ by 4″, and, of the many forms of loose-leaf note-books, "Walkers' University Expert," with duplicate hard-covers can be specially recommended. This type permits notes and records as they are made to be detached and filed securely under the duplicate hard-covers.

Mounting Methods.—Adult Insects. An unrivalled method of mounting mosquitoes (or, for that matter, any small insects) is the transparent-stage system. This system has many advantages :

it makes it possible to view the dorsal, lateral and ventral aspects of the mounted insect even under the microscope; it ensures that both the supporting-pin and the mounting-pin are held permanently secure; and it enhances the appearance of any collection. Two transparent materials can be used in making the stages, namely, sheet celluloid and "artist's gelatine." The former material is preferable, as it is unaffected by variations in atmospheric humidity and temperature, while, unfortunately, the gelatine is not. Moreover, the artist's gelatine is often difficult to obtain, except at large commercial centres. Celluloid-sheet, on the other hand, now that the motor-car and its attendant garage are to-day to be found, even at the outposts of civilisation, can be easily obtained. The best thickness of either the sheet-celluloid or the artist's gelatine for the stages, is 0·5-1·0 mm. Celluloid has only one disadvantage, it is highly inflammable if brought into direct contact with a flame, and for this reason its use is proscribed by some insurance companies. With ordinary intelligent care, the fire-risk with celluloid is negligible, and since it is a material which can be obtained readily, there is no necessity to have a large stock on hand. If a fair-sized sheet is bought, and a square foot cut off, the remainder of the sheet can be rolled and stored out of harm's way.

The best size for the stage when mosquitoes are to be mounted is $\frac{3}{8}''$ by $\frac{5}{8}''$, and a convenient method of forming these stages is to rule two series of lines at right angles across a square foot of the transparent material so that the whole sheet is divided into $\frac{3}{8}''$ by $\frac{5}{8}''$ sections. The sheet should be laid on a smooth cloth-covered surface, and, by means of a flat (not circular) ruler and a mounted needle, a series of parallel straight lines, $\frac{3}{8}''$ from each other, are ruled across the sheet in one direction, and

another series of parallel straight lines, $\frac{5}{8}''$ from each other, are ruled in the other direction at right angles to the first set of lines. This results in the formation of 604 $\frac{3}{8}''$ by $\frac{5}{8}''$ sections with a minimum of waste material. Keep the ruled sheet intact until the stages are wanted, and then cut off one entire strip at a time instead of snipping out a section here and there as required. If there are more stages in the entire strip than are needed at once, attach the remainder of the strip to the main sheet by means of a wire paper-clip. It will be found that this method greatly facilitates the handling of the stages.

To prepare the mounted stage, proceed as follows: From the strip of celluloid cut off one of the $\frac{3}{8}''$ by $\frac{5}{8}''$ sections. Lay the section on a flat piece of cork, and, by means of a fine mounted sewing-needle (preferably No. 8), pierce the section in the median longitudinal line once at a distance of about $\frac{1}{8}''$ from the edge at one end, and again about $\frac{1}{4}''$ from the other end of the section. In making the latter hole, only allow just the point of the needle to penetrate the section so as to ensure that the diameter of the hole will not exceed the diameter of the fine No. 19 or No. 20 pin which is to be inserted. Through the hole that is $\frac{1}{8}''$ from the edge of the section, pass a No. 2 or No. 11 pin, and slide the section up the pin until the upper surface is about $\frac{1}{4}''$ from the pin's head. Holding the mounted stage by means of the pin, now turn the upper surface of the stage downwards on to a large smooth-surfaced bottle-cork, allowing the projecting pin's head to lie parallel with the side of the cork. By means of pin-forceps, insert a No. 19 or No. 20 pin into the other hole in the stage, and in this manner the point of the No. 19 or No. 20 pin will project from the stage's upper surface. Drive this pin carefully through the stage up to its middle point. As many stages as

are required should be prepared beforehand in a similar way. In the subsequent instructions the No. 2 or No. 11 pin will be referred to as the "supporting pin," and the No. 19 or No. 20 pin as the "mounting pin" *(Fig. 45, below)*.

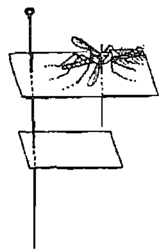


FIG. 45

ILLUSTRATION OF CELLULOID MOUNTING-STAGE AND PINS

Showing mounted mosquito on celluloid stage, and small label card below

Mounting the Mosquito. If the insect is alive, transfer it to a clean and perfectly dry large specimen tube, cover the mouth of the tube by a fold of mosquito netting, and allow the vapour of chloroform or ether to enter the tube by tilting the mouth of the bottle of anæsthetic over the mouth of the tube. On no account allow even a drop of the anæsthetic to enter. Watch the effect carefully, and immediately the insect falls stunned, tip it out on to a clean piece of smooth-surfaced paper. The stunned and almost completely paralysed insect must now be carefully turned on its back with the aid of a needle, and holding a mounted stage by the supporting pin, the point of the fine mounting-pin is directed to the middle of the ventral surface of the thorax between the legs. Very gentle pressure is sufficient to cause the point of this pin to enter the thorax, and it should be well embedded in the thorax vertically, but not be pressed through far enough to project from the dorsal surface. As soon as the insect has been thus impaled, it can be lifted, attached to the

pin, from the paper, and the upper surface of the thorax should then be very gently pressed against the operator's thumb-nail to ensure that the point of the pin just penetrates the dorsal surface of the thorax and firmly secures the insect. All the movements in the operation must be exceedingly gentle and be devoid of all rubbing action, or damage to the scale vestiture will occur. If the brief action of the chloroform has not already brought about a fully expanded condition of the wings—which in most instances will be found to be the case—a needle should be carefully slipped between the wings as they lie over the abdomen, and be made to press each wing in turn outwards and forewards, when it will usually be found that the wings remain in fixed extension.

The next step in the process is to draw the insect on the fine mounting-pin down towards the stage surface so that the legs can be symmetrically arranged. To accomplish this, with the fine pin held securely by the celluloid through which it passes, is rather a difficult matter unless it is done in the following way: Hold the stage by placing the finger and thumb of the left hand so that the lower surface of the stage rests upon the upper lateral aspects of the finger and thumb, while at the same time they lightly grip the lower stem of the mounting-pin (*see Fig.* 46, *page* 200). Then, with pin-forceps held in the right hand, grip the mounting-pin near its head, and it will be found that by simultaneous pressure applied by the fingers against the under surface of the stage and to the pin-forceps, the pin can be drawn through the stage slowly without the least danger of suddenly pulling the pin too far and leaving the insect detached from the mounting-pin on the top of the stage. Lower the mosquito until all its legs will touch the edges of the stage, and then, with a needle, carefully arrange the legs in such a way that each pair is

symmetrically spread with the mid- and fore-legs attached to the edges of the stage by their claws, which will be found to act as efficient anchors. Then lower the body of the insect by drawing the mounting-pin still further through the stage until the ventral surface of the body is about $\frac{1}{8}''$ from the stage surface. Finally, to complete the work, carefully drive the point of the supporting-pin

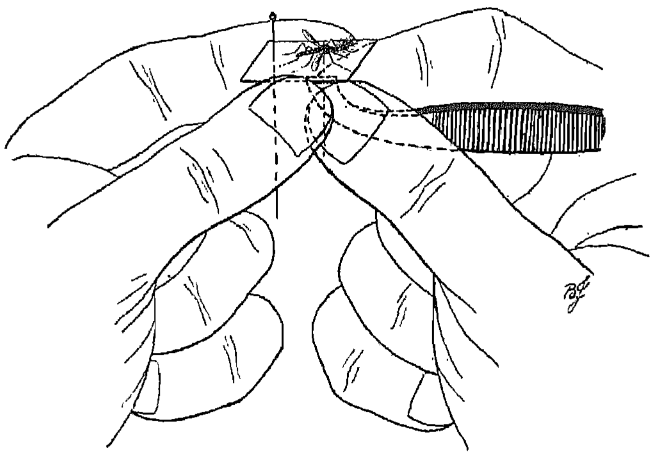


FIG. 46

SHOWING METHOD OF ARRANGING THE SPECIMEN ON THE CELLULOID STAGE

into the lower end of a cork which fits a large diameter collecting-tube in which chloroform-saturated cotton-wool has been placed. Insert the cork carrying the mounted insect in the tube for two minutes to kill and fix the specimen, but it must not be left in the saturated chloroform vapour for longer than two minutes, otherwise the constituent camphor in the celluloid will crystallise out on the stage. If careful attention cannot be given to this part of the process, it is better to kill the insects in hydrocyanic gas from an ordinary cyanide killing-bottle.

It should be noted that the action of chloroform vapour upon insects' muscles has two separate phases. The first is a paralysing action in which the muscles are flaccid, enabling the limbs to be placed by the operator easily in all positions ; and the second phase, brought about by the continued action of the anæsthetic, causes rapid death with all the limbs in inflexible rigor. It is these two phases of the anæsthetic that are here utilised in mounting and finally fixing the insect in symmetrical arrangement. Unfortunately, the rigor is of comparatively temporary duration, and often the subsequent desiccation of the insect-body distorts the legs out of the exact positions in which they were originally placed, but frequently, however, this does not happen, and, in any case, the final appearance is good.

Although mosquitoes, as a rule, should be mounted upon the stages in an upright position, yet if there are many specimens of the same species, some are advantageously mounted in the lateral position by passing the mounting-pin through the thorax from side to side, inserting the point of the pin just below the base of one of the wings. The wings should be extended at right-angles to the body in the manner already described, but there is no necessity to arrange the legs, which will be found to stretch out stiffly as soon as the insect is killed in the chloroform vapour. In laterally mounted insects, it is well to revolve the mounting-pin so that the legs of the insect touch, or at least point towards, the neck of the supporting-pin ; thus, as far as possible, avoiding the likelihood of damage to the legs.

In connection with the preparation of successfully mounted mosquitoes, it should be borne in mind that insects which have only recently emerged from the puparia cannot be successfully mounted. In these insects the exo-skeleton is so soft that it

does not resist the distortion which takes place through the drying-up of the internal tissues after death, and consequently, a newly-emerged insect, if mounted, soon becomes so shrivelled and distorted as to be useless as a specimen. Moreover, the colour markings of a mosquito take several hours after emergence to become fully developed.

Mosquitoes which have been bred in the laboratory, or which have recently emerged elsewhere, should be released into a clean wide-mouthed bottle, and the atmosphere in the bottle should be kept humid by hanging over the lip one end of a strip of narrow lamp-wick, the other end of which dips into a small water-reservoir. The mouth of the bottle should then be closed by placing a small glass sheet on the top of the wick. Mosquito-netting should not be used to imprison the insects, as the aim is to prevent the living mosquitoes within the bottle from flying upwards and striking the thorax against a rough surface and so to damage or remove the scale ornamentation. The bottle containing the specimens should be well shaded from direct sunlight, and they should not be mounted until 24 hours after emergence. It is even better to wait until the insects will take a meal of blood and then to mount them 12 to 24 hours afterwards, as this largely prevents shrinkage of the abdomen and is a valuable method when any particular specimens are wanted with as little distortion as possible.

Mounting Dead and Dried Insects. In most cases mosquitoes which are already dead and dried, and which have perhaps been kept together in a small box or tube, do not generally make satisfactory specimens for collections, as much of the scale ornamentation is apt to have been removed. If, however, they are to be mounted, the following is the procedure that should be adopted: Place

the insects carefully in a clean and polished watch-glass, set the glass on a piece of water-saturated cotton-wool, and cover both by inverting over them a small bell-jar, finger-bowl, or similar vessel, and leave the insects in the moisture-saturated atmosphere from three to four hours. By that time it should be found that the limbs and bodies of the insects, which were previously dry and brittle, will have become comparatively soft and pliable. They can then be mounted on the stages easily in the manner already described.

Preserving and Mounting Larvæ and Pupæ

Preservation. Larvæ and pupæ should first be killed by being placed in hot—but not boiling—water. Water at 120-140° F. is about the right temperature. In order to avoid damaging the hair characters, the larvæ and pupæ are best lifted from the water by means of a wide-bore pipette (*page* 234), and by this means they are transferred to a watch-glass. When all the larvæ are together, the water in the watch-glass is drained off, and a small quantity of the preserving-fluid is carefully poured into the watch-glass. This in turn is drained off, and a further quantity of the fluid added, from which the larvæ or pupæ may be collected by the wide-bore pipette and be transferred to small glass tubes containing more of the preserving-fluid. Preserved larvæ and pupæ which are to be despatched through the post should be placed in glass tubes of small diameter, filled with the preservative fluid and having the ends of the tubes plugged with cotton wool. These small tubes are then placed in larger glass tubes, while the spaces within the larger tubes are packed with preservative-soaked cotton-wool, when they may be corked and wax-sealed. In this manner, evaporation in transit is effectually prevented.

A special preserving-fluid which can be thoroughly recommended is :—

Borax, 0·5% = 10 c.c. of a 5·0% solution of borax.
Formaldehyde, 4% = 10 c.c. of a 40% solution of formaldehyde.
Glycerine, 0·25% = 0·25 c.c.
Water, 95·25% = water to make up to 100 c.c. (79·75 c.c.).

Alcohol can be used as a preservative, but it has the disadvantage of hardening the specimens and causing considerable distortion. If used, the larvæ and pupæ must first be killed in hot water, and then be transferred to 30% alcohol for 12 hours before being finally placed in the 70% alcohol preservative. A small amount of glycerine (2 c.c. to every 100 c.c. of alcohol) is advantageously added if alcohol is used.

Mounting Mosquito Larvæ and Pupæ. The Whole Specimen. There are two separate aims in mounting mosquito larvæ and pupæ; the first is to mount the specimen in such a way that its life-like appearance is preserved as much as possible; and the second is to mount it in such a way that the external specific characters are exhibited in complete detail. In the first case the specimens are mounted in sealed cell-slides containing simply a small quantity of borax-formaline preserving-fluid, and in the second case the specimens are treated with weak sodium or potassium hydroxide to dissolve the internal tissues, and are later mounted under pressure in canada balsam.

Construction of Cell-slides. To construct the cell-slides, ordinary 3″ by 1″ microscopical slides and pure tin-rings are used. The latter are obtainable from most dealers in microscopical supplies, and two sizes should be obtained, namely, those with an external diameter of ⅝″, and others of ⅞″. The former will be found to be the most

convenient size to use in most instances. When the cell-slides are to be prepared, see that the tin-rings are perfectly flat by placing them on a piece of sheet glass and observing whether the entire under-surface of the ring lies in contact with the glass surface. If not, remove the ring and press it between two pieces of wooden board, which will be found satisfactorily to flatten the soft metal ring. Usually this will be unnecessary, as the majority of the rings, when purchased, are quite flat. To carry out the proper construction of the cell-slides, the operator should be seated at a table before a window so that the work is illuminated by direct light—a matter of some importance, as will be seen later. As many clean and unscratched microscopical slides as will be needed are selected and placed in a row on the left-hand side of the worker, while the box of tin-rings is placed on the table in front. On the table immediately below the worker's hands, there should be a piece of white paper on which the outline of a microscopical slide is drawn, having a $\frac{3}{8}''$ and a $\frac{7}{8}''$ circle concentrically inscribed round the middle point of the slide. A slide is then taken from the left-hand row and placed exactly on this outline drawing. The circle will show through the glass and indicate where the tin-ring is to be placed. A ring is taken from the box, and, by means of a fine sable-hair brush, one flat surface of the ring is lightly painted with gold size, and the ring afterwards carefully lowered on to the slide so that its periphery as nearly as possible coincides with the pencilled circle of the corresponding diameter. The slide, with the ring adhering, is then carefully lifted and placed on the right-hand side of the worker, each subsequent slide being placed to form a row. When a sufficient number of slides have thus been dealt with, a turn-table should be arranged in front of the operator. In

order to allow a slight drying of the gold size which is already on the rings, the cell-slide whose construction was first begun should be gently placed upon the turn-table, and later each of the slides should follow in orderly sequence. Hence the object of arranging them in rows. The slide on the turn-table must be adjusted so that when the turn-table is revolved the tin-ring revolves without any eccentric movement. With this adjustment effected, clamp the slide in position by means of the turn-table clips. As the operator sits at the window, he should now notice that although everything is well illuminated by the light entering the window, the inner circumference of the tin-ring opposite his eyes is in partial shadow. In making this observation, his eyes should be at an angle of about 30-45° above the inner circumference of the ring. The turn-table is then spun with the left hand so that it is running at a speed of from 2 to 3 revolutions per second, and a fine sable-hair brush is well charged with gold size and applied *carefully* to the lower edge of the outside circumference of the tin-ring. In applying this gold size, hold the brush tangentially at an inclination of about 45° from the glass slide without causing any lateral pressure against the tin-ring. At least two well-charged brushes of gold-size will be required to cement the ring properly, but fortunately there is a perfect guide to the necessary amount. If, as the gold-size is applied, the operator keeps his attention directed to the inner circumference of the tin-ring, he will notice as the gold-size runs in below the under surface of the ring that the partial shadow (which was mentioned previously) is gradually replaced by a bright glistening line, due to the refraction of light. The formation of this ring of light takes place by the coalescence of what at first are bright spots and segments under the tin-ring, and the aim should be to apply only

sufficient gold-size to get a complete light-ring formed. Excess of gold-size will result in its spreading on to the glass surface enclosed by the ring, and so tend to spoil the work, while insufficient gold-size will not completely seal the lower surface of the tin-ring to the slide, and result in the formation of an imperfect air and water-tight joint. However, the proper construction of these cell-slides is extremely simple, and, if carried out as directed, no difficulty will be found in making slides that remain perfect indefinitely. As soon as the tin-ring has been sealed to the slides, the slides must be placed flat on a tray, and be stored in some warm dry place for two days to allow the gold-size to dry thoroughly. When dry, ring the slides once more, this time carrying a light coat of gold-size completely over the outer circumference and top surface of the tin-ring. This final coat will dry rapidly, and the slides are then ready for use. Batches of the cell-slides should be prepared from time to time, so that there will always be a supply available when they are required. If, before use, each slide is turned over and examined from the under side, faulty construction can be detected through the glass. In a well-constructed slide the colour of the under-surface of the tin-ring should present a uniform greenish colour, indicating that the gold-size has run in and completely united the glass and tin surfaces. Any areas which show as silvery patches or spots on the under-surface of the tin-ring indicate that the gold-size has not spread uniformly, and such slides must not be used. If they are placed in a wide-mouthed bottle containing turpentine, the ring will be detached from the slide, and, after proper cleansing, both can be used again.

Mounting in cell-slides. The larvæ, pupæ, etc., to be mounted should be killed by the hot-water

method in a watch-glass. If the specimens are dark in colour, the cell-slide in which they are to be mounted is advantageously laid on a piece of white paper, or, if the specimens are light in colour, place the cell-slide on a piece of black paper so as to get a contrasting background. With a capillary pipette fill the cell with the preserving-fluid until the surface of the liquid within the cell is distinctly convex. Then, by means of a small section lifter or fine sable-hair brush, lift the dead specimens from the water in the watch-glass, drain off the surplus water from the lifter or brush by tilting it against the edge of the glass, and transfer the specimen carefully to the fluid within the tin cell, arranging it with the aid of a needle so that it lies centrally on the glass bottom of the cell. Next, take a clean and well-polished No. 2 circular cover-slip of a size corresponding to the size of the tin-ring, and, holding it by its edges between the finger and thumb, slowly lower it horizontally on to the convex surface of the preserving-fluid and allow it to descend steadily until the glass cover-slip rests concentrically on the upper surface of the tin-ring. Owing to the convexity of the fluid-surface, the cover-slip touches the fluid first at its centre, and, as the cover-slip descends, the excess of fluid is driven out, and the cover-slip finally rests on the tin-ring without enclosing air-bubbles. The cover-slip should then be gently pressed downwards round its edges to expel all excess of fluid, and capillary and surface-tension pressures will be found to hold the cover-slip to the tin-ring fairly securely. With strips of blotting paper remove all the surplus fluid from the top of the cover-slip and off the slide, and allow the surface moisture to dry off. Then place the slide centrally on the turn-table and carefully run on a ring of gold-size over the junction of the edges of the cover-slip and the side of the tin-ring. Allow the gold-size to dry partially for

a moment or two and ring it with a second coat, when the slide can have its descriptive label and number attached, and must be placed in some situation for twenty-four hours exposed to the air to permit the gold-size seals to dry. At the end of the twenty-four hours, a third coat of gold-size is applied, this time fairly freely, so that it includes the side of the tin-ring and extends for about one-sixteenth of an inch on the glass slide all round the ring. Later on, when in turn this coat of gold-size has dried, a ring of black asphalt varnish may be put on, which greatly enhances the appearance of the work. Slides constructed in this way considerably reduce the labour of mounting specimens (avoiding the necessity of the lengthy dehydration process when canada balsam is used), and preserve the specimens in a life-like condition unobtainable by other methods. Moreover, when carefully handled, these slides keep in good condition almost indefinitely.

Mounting parts of the Larvæ, Pupæ, etc. Naturally the foregoing method of mounting the whole specimen assumes the use of only comparatively low powers of the microscope in the examination of the specimen. As these are the powers most commonly used when *whole* specimens are examined, there is no disadvantage in this method. When, however, *parts* of the specimen are to be mounted in order that they may be examined under high microscopical magnification, we have to resort to the canada balsam embedding process.

For the specimen-collection, whole specimens of the larvæ and pupæ should always be mounted in the cell-slides, and as comparison preparations there should invariably be balsam-mounted posterior sections, etc., from other larvæ of the same species, the reason for this being that,

although the whole specimens will present most of the generic diagnostic characters, the specific characters are frequently only to be seen on the lateral aspects of the posterior abdominal segments, and sometimes necessitate the use of high magnification before they are revealed. The balsam-mounted preparations are made as follows.

On the table in front of the worker, six watch-glasses are arranged in a row on a strip of white paper. No. 4 and No. 5 are to be provided with watch-glasses of corresponding or larger size, which, by being inverted so that the rim is in contact with the rim of the one below, the upper watch-glass will form an efficient cover to the lower. Fill the watch-glasses serially with the following reagents :—

Watch-glass No. 1, fill with 30% alcohol.
,, ,, ,, 2, fill with 50% alcohol.
,, ,, ,, 3, fill with 70% alcohol.
,, ,, ,, 4, three-parts fill with 90% alcohol.
,, ,, ,, 5, three-parts fill with absolute alcohol.
,, ,, ,, 6, three-parts fill with pure cedar-wood oil.

Cover watch-glasses, No. 4 and No. 5, with duplicate or larger watch-glasses to prevent rapid evaporation and absorption of water vapour from the atmosphere.

Kill the specimen in hot water as previously described, and, by means of a fine sable-hair brush, transfer it to a clean glass slide. Arrange the specimen so that it lies on its side on the glass slide, and with a sharp scalpel divide the body by cutting it transversely near the middle point of the abdomen. Well saturate the brush with water (in order that the posterior section of the larva may be lifted easily from the slide without damage), lift the section, drain off the surplus water from the brush by pressing the bristles against the edge of the slide, and transfer the section to the first watch-glass containing 30% alcohol.

Allow it to remain in the watch-glass for 15 minutes, occasionally moving it about in the fluid, and then transfer it to the next watch-glass containing the higher concentration of alcohol, in which it is to remain for a further 15 minutes before proceeding to the next. When the section is to enter the alcohol contained in watch-glass No. 4 and No. 5, the covers must be lifted and replaced after the section has been put in. On entering watch-glass No. 6, care should be taken to see that no cloudiness appears in the section. If so, the dehydration is not complete, and the section must be returned for a time to the 70% alcohol, and pass slowly through the 90% and absolute alcohol once more. If properly dehydrated, the oil should mix with the absolute alcohol carried to it by the section without any formation of cloudiness, and the section will, moreover, rapidly develop great transparency. The section may be allowed to remain in the cedar-wood oil as long as convenient, but it is better to proceed with the mounting at once. The mounting is completed by taking as many clean slides and cover-slips as there are specimens to mount, and placing on the middle of each slide a drop of canada balsam into which the specimens are inserted from the oil by the aid of a needle. As much as possible of the oil should be drained from the specimen before it is placed in the balsam, and it must then be carefully arranged in the balsam so that it lies on its side. Finally, a cover-glass is lowered horizontally over the drop of balsam containing the section. In this manner the balsam first touches the centre of the cover-glass, and, as it descends still further, the balsam flows out below the cover-glass and completely fills the space between it and the slide. Apply gentle pressure to the cover-glass by means of a pressure-clip, and set the slide aside to dry. Good preparations of the posterior segments of

larvæ in canada balsam are indispensable if the specific diagnostic characters which occur in the siphon, pecten and comb, etc., of all larvæ are to be studied. The same procedure may be adopted in the case of pupæ, when mounted preparations of the abdominal segments and telson are required to show any specific characters.

The whole larval skins may be similarly mounted if the larvæ are first boiled in 10% caustic soda solution until the internal tissues are completely dissolved, leaving nothing but the chitinous skin and external structures. Cast skins may be mounted in the same way, and do not, of course, need the caustic soda treatment.

Dissection and Anatomical Technique. The internal anatomy of the adult insects, as we have seen, is comparatively simple, and as the whole of the alimentary system as far forward as the posterior half of the œsophagus, together with all the organs of reproduction, may be easily removed in one operation, this may be considered the chief dissection. The only other dissection commonly necessary is the operation for the removal of the salivary glands, by which, in successful attempts, the anterior portion of the œsophagus, and the so-called "crop" or "food reservoirs" are at the same time also removed from the thorax. Almost all the remaining dissections that are of any importance may be termed simple snipping dissections. These consist in the removal of the wings to study the wing-venation in detail after the wing has been suitably mounted: the removal of the legs in order that the structure of the claws may be examined, the removal of the head and its appendages for the same purpose, and the removal of the terminal segments of male mosquitoes to study the structure of the external genitalia. The last may be considered as

a most important dissection to the more advanced student, as the structure of the genitalia varies greatly among the different species, and affords most valuable specific characters. Finally, there is what may be termed microscopical dissection by means of the microtome, where the whole of the body of the insect, or any part of the body separately, is cut into small films only some thousandths of an inch in thickness, making it possible to study the cellular structure of all the insect tissues.

To remove the Stomach, Malpighian Tubules, Hind Intestine and the Organs of Reproduction. Anæsthetise the mosquito with chloroform or ether vapour, and, with a fine pair of dissecting scissors, remove the wings and the legs. Upon a clean slide place a drop of water, or preferably a drop of 1% sodium chloride solution. With a pair of fine forceps hold the insect by the proboscis and dip it momentarily into 70% alcohol, and then place it immediately in the drop of fluid on the slide, where, owing to the covering of alcohol, it will easily be partially submerged. Place the slide on the stage of a dissecting microscope, and by means of two fine-pointed needles, one held in each hand, adjust the body of the insect in the fluid so that it lies on its side horizontally in the field of the objectives, the tip of the abdomen appearing on the right-hand side of the field of vision. Steady the body of the mosquito by placing the needle held by the left-hand across the thorax, and, with the point of the needle in the right-hand, make two tiny cuts in the integument of the abdomen, one on each side between the junctions of the 6th and 7th abdominal segments, as indicated in *Fig.* 47, *page* 214. Now sever the abdomen from the thorax as close as possible to the posterior aspect of the thorax, and place the

head and thorax in a small drop of the fluid on some other part of the slide out of the field of vision. Adjust the abdomen to the centre of the microscopical field, and place the sloped point of the left-hand needle at the position marked "B" in *Fig.* 47, *below,* at the same time placing the sloped point of the right-hand needle on the 7th abdominal segment just behind the two small cuts that were previously made in

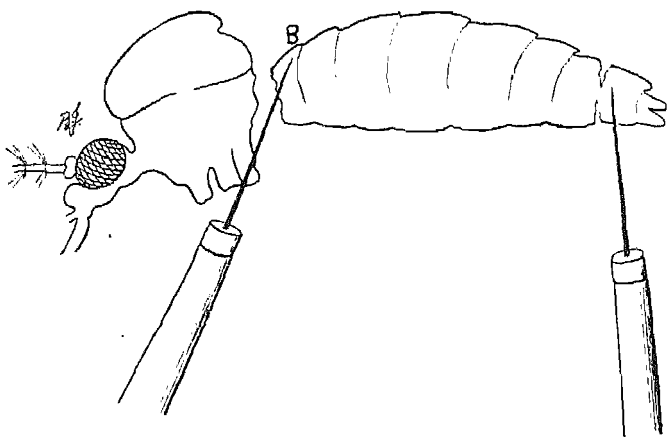


FIG. 47
A METHOD OF DISSECTING A MOSQUITO

the integument. Hold the left-hand needle steady, and with firm but light traction on the right-hand needle, pull the 7th segment and tip of the abdomen slowly and steadily from the anterior segments. A small section of the hind gut will be seen immediately the integument ruptures at the cuts, and, as the segments are pulled away from each other, one or two folds of the malpighian tubules will appear together—in female specimens with the lower portions of the ovaries as well. When these organs are visible, stop the progressive pulling action, but maintain the tension. This enables the abdominal

walls through which the organs are emerging to expand gradually, and gives time for the fine branches of the tracheæ to snap under the continued strain, so decreasing the risk of the hind gut breaking. As soon as the tension has decreased by the expansion of the abdominal walls, etc., the pulling action of the needle can be renewed, and by intermittent pulling, with short intervals of rest while the tension is maintained, the hind gut, malpighian tubules, stomach, reproductive organs and part of the œsophagus will finally be drawn out of the abdomen quite easily. Some workers do not sever the abdomen from the thorax in performing this operation, but pass the point of the left-hand needle through the thorax, in this way securing a hold on the body from which to pull. It is frequently quite a satisfactory method, but as the posterior end of the œsophagus is not cut through, a necessarily greater strain is put upon the hind gut in order to effect the rupture of the œsophagus before the stomach and other organs can be drawn out. Should the hind gut break and the tip of the abdomen thus become completely detached, the stomach can often be removed from the severed abdomen by securing a hold with one of the needles on the side of the posterior segments while pulling with the other needle on the posterior end of the œsophagus, thus drawing the stomach from the abdomen through its basal end.

The main object of this operation is, of course, the examination of the stomach for the presence of the oöcysts of the malaria plasmodia, but it also affords a ready method of estimating, from the condition of the ovaries, whether hibernation as the adult takes place; and, by an examination of the stomach contents, what animal serves as the host. In hibernating female mosquitoes the fat-body is hypertrophied, and, on dissection, the body

fluids will be found to be crowded with fat-globules, while the ovaries are small and have temporarily ceased to function.

Malarial oöcysts on the exterior wall of the stomach of anopheline mosquitoes may be recognised as highly refractile almost spherical bodies, usually of a transparent greenish tinge, ranging in size from a small dot, just visible under the 2/3rds objective, to large conspicuous spheres, according to the age of the cysts *(Fig. 48, below.)*

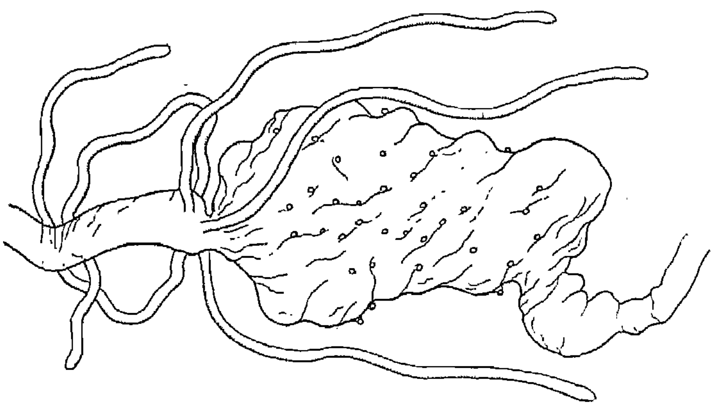


FIG. 48

MOSQUITO STOMACH

Showing the presence of numerous young oöcysts on the exterior wall

It should be remembered that oöcysts of other species of plasmodia are frequently found on the stomachs of the culicine mosquitoes which are the vectors of avian and reptilian species of hæmatozoa.

In freshly-fed mosquitoes it is sometimes possible to estimate fairly exactly the identity of the host by the size and character of the contained red-blood cells, and more exact information, if necessary, can be obtained by hæmatin reactions.

Permanent preparations of either one or all of the organs removed in this dissection may be made by lifting the organs carefully on the tip of a sable-hair brush—which has been previously dipped in 1% salt solution—and thus transferring them to the preservative in a cell-slide, afterwards sealing it in the manner already described; or the organs may be placed in Wassermann-reaction tubes containing the preservative solution, when only preservation and storage is the aim. If preferred, the organs can be mounted for examination under the compound microscope by fixing them in hot water (140° F.), then staining in borax-carmine, from which they are passed into 30% alcohol (which has been slightly acidulated by the addition of acetic acid in the proportion of one drop of acid to every 10 c.c. of alcohol), and afterwards carefully dehydrating in the ascending concentrations of alcohol. After clearing in cedar-wood oil, the specimen can be mounted in canada balsam, with or without pressure.

A Method of examining the Stomachs of Mosquitoes for Malaria Oöcysts. After dissection by one or other of the approved methods, the stomach will be seen to be either empty and flat, or, if the insect has had blood meals since the first infective meal, it may be partially distended with blood. In either case, young oöcysts may be overlooked unless precautions are undertaken. In empty stomachs which, in the process of being withdrawn from the body have been extended, much of the contained gas or air is forced out by the contraction of the diameter. When the removed stomach is freed from tension it attempts to resume its normal shape, but the weak contraction of the muscles and the partial vacuum within often leave it completely flattened. If the oöcysts are numerous or well-developed, they can still be seen

quite easily, but if they are young and few in number, it may well happen that what few there are lie on the upper or lower flattened surfaces of the organ, and they are then very easily overlooked. The flattened stomach may be made to resume its normal shape in the following way:—

On a clean microscopical slide place a drop of water large enough to accommodate and submerge the stomach. Transfer it to the water on the slide, and, with a rocking motion to prevent the organ adhering to the glass, gently heat the under-surface of the slide. As the water warms up, the stomach muscles undergo a vigorous contraction, causing water to be drawn in, and it resumes its normal shape. The careful application of heat to the under-surface of the slide should cease immediately the contraction of the stomach is observed. If the stomach is then examined under the microscope as it lies in the water, any oöcysts projecting from the curvature of the outer wall are conspicuous, and, by rotating the stomach with the aid of a needle, every part of the wall may be examined.

If the stomach contains blood, make a small incision in the wall and place it in a large drop of water on a clean slide. To this add a drop of 70% alcohol. Powerful diffusion currents will be set up which effectually evacuate the stomach of blood through the aperture made in the wall. If necessary, the process may be repeated by placing the organ in another drop of water and alcohol before it is finally placed, when free from contained blood, in a drop of water on a slide and heated carefully in an attempt to get it to resume its normal shape—as was done in the case of the empty and flattened stomach. Nine times out of ten it will be found that contraction of the muscle walls takes place. The stomachs may be satisfactorily preserved, either by mounting them in cell-slides

in the formaldehyde-borax solution or by placing them in the same solution in Wassermann test-tubes.

To remove the Salivary Glands, Anterior Portion of the Œsophagus and Food Reservoirs. Either the remaining portion (head and thorax) of the body of the insect which has served for the foregoing dissection, or another whole insect, can be used for this dissection. If a fresh insect is the subject, remove the wings and legs, as before, and adjust the body in the salt solution on the slide in such a way that the head appears on the right-hand side of the microscope field. Carefully insert the left-hand needle into the posterior latero-dorsal angle of the thorax until the point of the needle strikes the surface of the glass slide. This will hold the thorax securely. In performing the operation, it should be remembered that the salivary glands are embedded in the thorax at a point a little above the attachment of the middle pair of legs, and consequently this area of the thorax must be guarded from injury. Avoiding the neck, drive the point of the right-hand needle obliquely through the back of the head, so that the needle-point rests against the posterior margin of one of the compound eyes. Then, with slow forward and downward traction with the right-hand needle, drag the head away from the thorax. If successfully managed, the neck will rupture close to its junction with the thorax, and the salivary-glands, their ducts, the anterior portion of the œsophagus and the food reservoirs will be pulled out of the thorax. The food-reservoirs will be recognised as three very thin-walled sacs which usually contain bubbles of gas, while the salivary glands are paired, highly refractile organs recognised easily by their sausage-shaped acini. Each complete gland consists of two sausage-shaped members with a third and larger tubular member lying between the other two.

The separate short ducts from each of the glands anastomose to form one of the pair of salivary ducts which run forward from the glands to the base of the proboscis.

If the glands are to be examined for the sporozoites of the malaria plasmodia, they should be removed from the head and be placed in a drop of 1% salt solution which has been slightly acidulated with acetic acid—1 drop to 10 c.c. of salt solution—on a slide. The glands are protected with a cover-slip, the excess of salt solution being extracted from between the slide and cover-slip by means of blotting-paper, until the cover-slip presses the glands quite flat. Should the glands rupture under the pressure of the cover-slip, no harm will be done, as any sporozoites that may be contained, will be set free and then be easily seen. The sporozoites are slender siccle-shaped bodies from 12 to 14μ in length, with a single small nucleus at the centre. They may be made more clearly obvious either by staining the whole gland with Leishman stain or by making a smear-preparation from the glands and staining with the same stain. Christophers and Stephens (1900) drew attention to the fact that the salivary glands of mosquitoes often normally contain certain bodies which in appearance closely resemble sporozoites. Wenyon (1921) has pointed out that what are probably the same bodies in the salivary glands are actually acicular crystals of some substance which in shape closely resemble sporozoites, but that these crystals are rapidly soluble in acids. I have found a convenient method of avoiding confusion by the presence of such crystals is to acidulate the salt solution.

To Mount the Wings to show details of the Venation. In some species of mosquitoes, and even in some particular members of a species, the

position of the cross-veins and other details are invisible in the normal condition of the wings. This, however, is comparatively rarely the case, but when the required details cannot be seen, all the details of the venation pattern can be brilliantly revealed by the following method: Cut off the wings as close to the thorax as possible and place them in 90% or absolute alcohol to remove the air contained in the lumina of the veins, and remove them to a hot solution of carbol-fuchsine in which they should be kept for at least an hour. Then lift the wings to a watch-glass containing 70% alcohol and wash carefully until the wing membrane loses its colour while the veins remain deeply stained. Dehydrate in absolute alcohol, clear in xylol and mount in canada balsam. All the veins will then be stained a deep magenta colour, and, contrasting conspicuously with the colourless wing membrane, their structural details can be minutely studied.

To Mount the Legs of Mosquitoes to show the Structure of the Claws. The fore and middle pairs of legs of mosquitoes often carry at the tips of the 5th metatarsi fairly large claws, the characters of which are used in classification. Such claws may be simple, or toothed in various ways, and in the identification of a species the feet have not infrequently to be examined under the microscope to study the claws and the presence or absence of empodia (*Fig.* 8, *page* 41; *Fig.* 34, *page* 148). The necessary examination can usually be carried out fairly well under the dissecting microscope, even in pin-mounted specimens when a *high* power objective is employed, but it is far more satisfactory to make microscopical preparations, which serve as permanent references. The method is extremely simple. With a pair of fine dissecting scissors snip off one of the fore, middle and hind pairs of legs

at their articulations of the 1st metatarsi and the tibiæ. Place the legs in absolute alcohol for a few minutes, transfer them to xylol to clear, and mount the three legs, evenly spaced, on a slide in canada balsam. Make it a rule with these preparations to adjust the legs in parallel arrangement with the middle leg between the fore and hind legs. This will ensure rapid identification of any of the legs, as the tarsi of the hind legs are always markedly longer than the tarsi of the anterior pairs of legs.

To Mount the Head and its Appendages. With a pair of fine dissecting scissors cut through the neck of the mosquito, passing the blades of the scissors between the head and thorax. Place the severed head in a little 10% caustic soda solution in a watch-glass. Heat over a small flame until the eyes lose their pigment and the soft tissues of the head have been dissolved. Then, with a section-lifter, transfer the head to distilled water; wash, dehydrate in the alcohols, clear in cedar-wood oil, and place the head, with its dorsal aspect uppermost, in a drop of canada balsam on a clean slide. With the aid of a needle, arrange the palpi so that they lie separated one on each side of the proboscis, and dispose the antennæ in a similar manner. Lower a cover-glass on the specimen and hold it in position by a pressure-clip until the balsam is dry. Frequently, by this method of mounting the head, the separate components of the proboscis will be found to have partially sprung from their sheath, and their structure may thus be conveniently studied.

To Mount the Male Genitalia. Except for the fact that the specimens are obtained by snipping off the tip of the abdomen at the 6th segment, the technique of mounting the male genitalia is the same as the foregoing, *i.e.*, the tip of the abdomen

is boiled in caustic soda for a few minutes to render it soft and more transparent, and it is then dehydrated, cleared, and mounted in canada balsam. Note, however, that the specimen should be mounted on the slide with its ventral aspect uppermost.

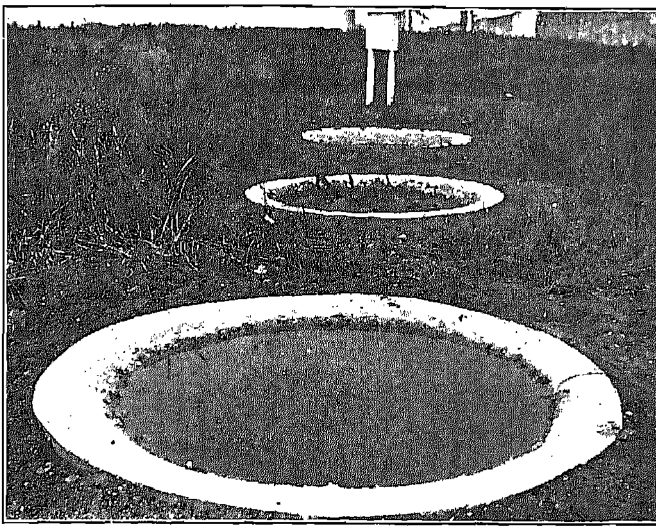
Breeding and Rearing Technique. Eggs. In order to obtain the larvæ from collected eggs, the eggs should simply be floated on the surface of water taken from the site of the normal breeding-place. If such water is not available, or is unknown, the larvæ of most anopheline species (except tree-hole breeders) will be found to do best in clean water with an alkaline reaction, in which there is living vegetation; while most culicine larvæ (except the tree-hole breeders) do well in rain-water in which there is a fair supply of decomposing vegetation. The tree-hole breeders of both anopheline and culicine species usually demand an acid water for successful development, in which there is a large supply of the organic products of vegetable decomposition. For this group, rain-water, slightly acidulated with acetic acid and containing a few fallen leaves of some non-poisonous plant, will be found an excellent medium for the development of the larvæ.

Floating Egg-Harbours. If the eggs of mosquitoes are allowed to float freely on the surface of water while they are undergoing development, they naturally tend to drift to the sides of the container, and, by evaporation of the water, with the consequent lowering of its level, are apt to become stranded and killed by desiccation. This can be avoided by cutting out the centre of a large cork with a $\frac{1}{2}''$ diameter cork-borer, and subsequently cutting the cork across its width into cork rings about $\frac{1}{8}''$ thick. These rings should be soaked in

molten paraffin-wax to render them waterproof, and then be placed on the water. The eggs are readily lifted from the water-surface with the aid of a wet sable-hair brush, the tip of the brush being brought up under each egg, and in this manner they are transferred to the water surface within the cork ring. Obviously, any rise or fall in the level of the water will now not affect the eggs, as the cork harbours will always rest on the surface, while the larvæ which hatch, by naturally descending, escape from the confines of the ring into the main body of the water (*Fig.* 49, *below*).

FIG. 49
FLOATING EGG-HARBOURS

Larvæ. The rearing of larvæ in a laboratory is an art in itself. The larvæ of some species of mosquitoes are so hardy (for example, *Aëdes (S.) argenteus*, *Culex fatigans*, etc.) that they will develop successfully in almost any water and in any situation; provided only that the water is neither strongly acid nor strongly alkaline, and contains a non-poisonous organic material which may act as a food. On the other hand, most anophelines demand for their successful development the closest attention to details on the part of the laboratorian, so that the conditions in the laboratory rearing-dishes may as nearly as possible reflect the natural conditions of the normal breeding-place. The reaction of the water must, within close limits, conform to the pH. index of the breeding-places in nature; with the majority of species the water must be kept strictly fresh; the presence of living vegetation (algæ in some cases,



SERIES OF MOSQUITO PONDS

FIG. 50.—Cement Rearing-basins, in the open

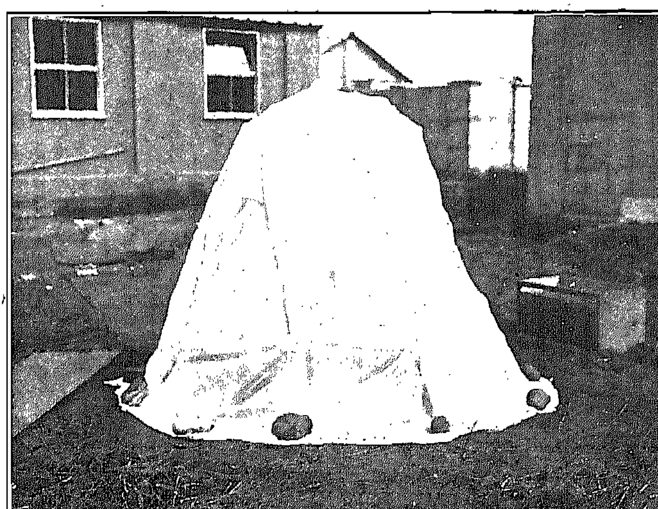
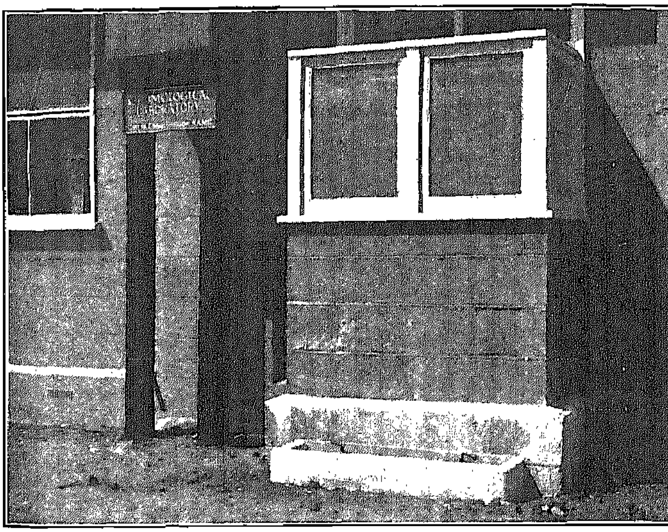


FIG 51.—Method of capturing emerging adult mosquitoes from cement rearing-basins



WAR OFFICE LABORATORY

FIG. 52.—Semi-out-of-doors rearing cage

WISLEY LABORATORY

FIG. 53.—Bench type of insect-cage

Wellcome Bureau of Scientific Research Laboratory, Wisley

or the higher plants in others) must be ensured; the necessary degree and amount of direct or indirect sunlight falling on the water-surface must be maintained, etc. For the rearing of any really large number of the commoner anophelines at the laboratory, undoubtedly the best method is to construct shallow cement basins out of doors which are filled with the water and plants from the natural breeding-place (*Fig.* 50, *facing page* 224). The emerging adults can be captured in mosquito-net balloon-coverings placed over the basins (*Fig.* 51, *facing page* 224), and the two sexes, being transferred together to cages in the laboratory and suitably fed, will, in most instances in the Tropics, be found to furnish large numbers of fertilised eggs which, in turn, may be transferred to the rearing-basins to hatch; the succeeding generations thus being maintained. When a less ambitious method is desired, close study of breeding-technique has convinced me that the most satisfactory medium in which to rear most anopheline larvæ (excepting the tree-hole breeding species) is ordinary (slightly alkaline) tap-water, to which is added a few living grass-plants with a small amount of soil attached to their roots. The water and plants should be placed in glass finger-bowls or other non-metallic dishes, where a comparatively large water-surface will be exposed. These dishes are then set out of doors either in direct or indirect sunlight, as indicated by the normal breeding-place. Larvæ in the tap-water, plus grass-root medium, have in general been found to do better than if kept in water from the breeding-place. It is sometimes possible to construct semi-out-of-doors mosquito-cages by building special cages outside one of the laboratory windows (*Fig.* 52, *opposite*). In this manner the laboratory worker can control the insects from within the laboratory while the insects themselves obtain fresh air and sunlight.

In rearing the majority of culicine larvæ at the laboratory less difficulty is encountered, and most species do well if placed in the water of the breeding-place plus some weeds and detritus from the site. Care should, however, be taken to see that the normal degree of daylight is provided.

With the anopheline and culicine tree-hole breeding species the larvæ do best if placed in the water of their respective tree-holes, but it is highly important in this case to estimate the original pH. index of the tree-hole water and to maintain this index by suitable additions of dilute acetic acid from time to time. Moreover, the normal degree of lighting must be strictly guarded, if necessary, by shading the rearing-dish with opaque paper.

The Influence of Alkalinity and Acidity in the Waters of the Natural Breeding-places. It has been shown recently that alkalinity and acidity in waters has a marked bearing upon the development of particular species; the larvæ of some species being found only in waters with an alkaline reaction, while the larvæ of others are found only in acid waters. Many species of both the acidophile and the alkalinophile larvæ will undergo development successfully solely in waters within a definitely short range in the degree of acidity or alkalinity. On the other hand, a few species seem to tolerate waters having either an acid or an alkaline reaction, but such species are less common than those which evince a marked demand either for alkalinity or acidity in the waters of their breeding-places.

So far, the observations that have been made on this phenomenon seem to prove that a particular species which demands, let us say, alkalinity in one situation, is most frequently found to make the same demand in other situations, and often an important clue is thus provided as to whether or

not a certain water may serve as a breeding-place to that particular species. In other words, waters having a decidedly acid reaction may be safely said not to provide a breeding-place for the alkalinophile species and waters with a definitely alkaline reaction will not harbour the acidophile species.

In some instances this fact has already proved of direct service in indicating which may and which may not be regarded as potential breeding-places for certain dangerous species.

Additional investigations on this subject are urgently needed from all parts of the world, for it may be found ultimately that in this a means of further concentrating control measures against only the important species is indicated.

Records have already been published by several investigators, and an analysis of these tends to show the following points :—

1. There are definitely acidophile and alkalinophile species.
2. There are also a few species which, to some extent, tolerate both acidity and alkalinity.
3. The majority of pond-, swamp- and river-breeding anopheline species are alkalinophile.
4. A lesser number of anopheline larvæ have, however, been found to occur in acid waters, and are acidophile.
5. Nevertheless, there does not appear to be any record of what is generally an acidophile anopheline species being found also in alkaline waters, or vice versa.

A considerable amount of work has been done in efforts to determine what influence the reaction actually has on the larvæ of particular species. It has been suggested that the reaction of the water plays an indirect part in affecting the development of the larvæ by favouring or, alternatively, checking the normal food supply ; or that it indirectly plays

its part by increasing or, alternatively, decreasing the potency and number of the organisms responsible for larval diseases. However, certain experiments seem to show that this explanation is not entirely satisfactory, for larvæ which have been placed in bacteria-free and nutritionless water are still noticeably subject to the influence of the reaction of the water itself. Moreover, that even when the larvæ in bacteria-free water (obtained by passing the natural water through bacterial-filters) are fed on sterilised food such as hard-boiled egg-yolk, boiled rice, etc., their successful development still depends largely on the correct degree of alkalinity or acidity.

Consequently, at present, it must be confessed, the correct explanation has still to be discovered, but, whatever the explanation may be, the phenomenon has, to some extent, a decidedly valuable application in field observations, and it is advisable that the estimation of the reaction of the water of all breeding-places should be adopted as a routine procedure in the hope that collected records will thus establish generally a possible limitation to the necessary control measures.

The Estimation of the Reaction of the Water in Mosquito Breeding-places by means of pH. Indicators. The symbol pH. is used for the expression of the degree of acidity or alkalinity in terms of the reciprocal of the exponent of the hydrogen *ion* concentration. When compounds are dissolved in water, not only does solution (molecular division) of the compound take place, but a proportion is split up into acidic and basic radicles which carry electric charges and are known as *ions*. The ion possesses either a positive or a negative electric charge according as to whether the molecule belongs to an element of the electro-positive or electro-negative series. Hydrogen being

electro-positive and oxygen being electro-negative, the hydrogen ion possesses a positive, and the oxygen ion a negative, charge. The molecule of water (H_2O) is electrically stabilised by the fact that the sum of the positive charges on the two hydrogen atoms exactly balances the negative charge on the single oxygen atom. Consequently, the hydroxyl radicle OH is obviously electrically unbalanced, since it has a preponderant negative charge. Hydrogen ions, then, are positive and hydroxyl ions are negative. Acidity is associated with a preponderance of hydrogen ions and alkalinity with hydroxyl ions.

By the use of certain unstable dyes (*i.e.*, dyes whose molecules are electrically unbalanced and which will consequently attract and attach to themselves ions of opposite sign), we are able to estimate the degree and quality of the ionisation (*i.e.*, the alkaline or acidic reaction of a liquid) by the colour changes occurring when the dye absorbs the particular ions of opposite sign which happen to be available. By the attachment of the ion to the dye molecule an unstable change in the molecular construction of the dye is brought about, resulting in a remarkable alteration in the particular wave-length of light that is reflected. We are thus able to estimate the reaction of a liquid by adding these dyes and observing the resultant colour.

Some of the dyes absorb electro-positive ions and other electro-negative ions. Each of these dyes or indicators is useful over a restricted portion of the pH. scale only, which is known as its range. Since stable solutions of known pH. can be prepared, it is possible to determine the pH. of an unknown solution by comparing the colour it produces with a given indicator with those produced in solutions of known pH. containing the same indicator. As some indicators are sensitive to the more acid end and others to the more alkaline

end of the pH. scale, a carefully-adjusted mixture has been placed on the market by the British Drug Houses, Ltd., of London, under the name of the B.D.H. Universal Indicator. This gives well-marked colour changes from pH. 3 to pH. 11 and covers the range of the pH. values most generally met with. The single fluid indicator considerably simplifies the work of estimating the reaction of a liquid, and in most cases gives a sufficiently close estimation to within ·5 of the whole number indices. Closer estimations of the pH. can be obtained, if necessary, subsequently by the employment of separate solutions of the individual dyes in conjunction with the "Capillator" apparatus manufactured by the same firm.

A preparation known as the "W.W. Universal Indicator," manufactured by the Wallis Laboratories, Watford, England, has recently been demonstrated to me, and has the distinct advantage of covering a wider pH. range, *i.e.*, pH. 1·0-pH. 12·0.

To test the Reaction of the Water of a Mosquito Breeding-place. The technique is very simple and should always be undertaken and recorded, as collected records will be found to give much useful information in regard to particular species.

The only apparatus necessary for this work in the field are a few thoroughly clean small glass tubes, a bottle of the indicator, an 8" length of narrow-bore glass tube, and one or two glass pipettes for collecting samples of the water to be tested. Collect a quantity of the water by means of the pipette and transfer it to one of the clean glass tubes. Wash the interior of the tube thoroughly by shaking up the contained sample of water, and empty the water on to the ground—*not* back into the breeding-place. Repeat the operation three times to ensure that the walls of the tube and

those of the pipette have no influence on the reading obtained. For the fourth time collect finally about 10 c.c. of the water in the tube, remove the cork from the bottle of indicator and insert the 8″ length of glass tubing. Allow the indicator fluid to rise up the bore, and close the open end of the tubing by pressing a finger tightly against it. Remove the tubing (which now contains a supply of indicator) from the bottle, and, holding it above the open mouth of the water-sample tube, and by suitably easing the pressure of the finger on the end of the tubing, allow from 3 to 4 drops of the indicator to fall into and mix with the water sample. With the " W.W. Universal Indicator," 10 c.c. of water to 0·1 c.c. (approximately 1 drop) of indicator are used. Shake the tube to mix the indicator and water completely, and the colour then indicates the pH. index according to the colour series given on the label attached to the bottle of indicator. The neutral point is pH. 7; acidity and increasing degrees of acidity are represented by descending indices below pH. 7, while alkalinity and increasing degrees of alkalinity are represented by ascending indices above pH. 7.

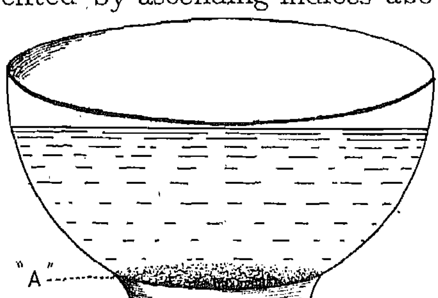


FIG. 54.—GLASS FINGER-BOWL REARING DISH
A, detritus collected at centre

Rearing-dishes. After considerable experience in the use of many common vessels as rearing-dishes, I have found that an ideal rearing-dish for the larvæ of most species is the plain (and cheap) glass

finger-bowls which are usually obtainable everywhere, particularly in the Tropics. Finger-bowls present a relatively extensive water-surface, while the depth of the water, even when the bowl is full, is not excessive, and the larvæ and pupæ, if necessary, are thus easily kept under observation. An additional advantage is that the semi-spherical curvature of the bowl causes detritus, and any dead larvæ or pupæ which sink, to be concentrated at the bottom—a position from which unwanted material is easily removed. (*Fig.* 54, *page* 231, will make this plain.)

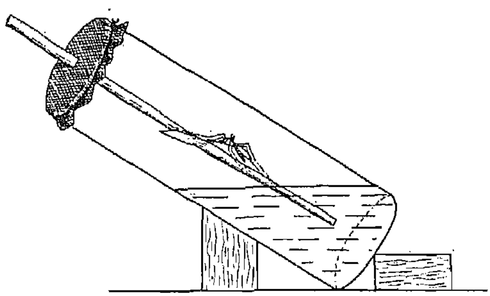


FIG. 55
APPARATUS FOR REARING INDIVIDUAL LARVÆ OR PUPÆ

Rearing Individual Larvæ or Pupæ. In localities where new species may be encountered it is of the greatest importance that new or unusual specimens are placed under the most favourable conditions for their development. If a rare larva or pupa is placed in the finger-bowl rearing dishes in the presence of others, there is considerable risk of its being lost sight of, and the rare specimen is also left exposed to many of the ordinary risks to its life. Rare larvæ or pupæ, or particular specimens which are required to develop under conditions that, as far as possible, ensure safe development to the adult state, should therefore be placed separately in glass tubes containing a supply of the water in which they were found. It is advisable, before the

specimens are placed in the water, to pour a small quantity first into a white photographic dish, and to remove other dead larvæ, small crustacea, other insect larvæ or aquatic mites which may be present, before putting the water into the tube. Fill the tube to about one-third of its capacity and, after the specimen has been added, close the mouth of the tube by tying over it a small square of mosquito-netting. Incline the tube at an angle of 45° by supporting it on two corks or wooden-blocks—as indicated in *Fig.* 55, *page* 232. As soon as the specimen reaches the pupal state, insert a piece of straw through the netting to afford the insect a support on which it may climb after it emerges from the puparium. Specimens reared in this manner have little inclination to fly about in the confined space of the tube, and the ornamentation thus remains undamaged.

Pipettes for Handling and Collecting Larvæ. In order to remove separate larvæ or pupæ from one rearing dish to another, or from the water in the breeding-place to the collecting tube, the easiest method is by the use of small pipettes similar to the well-known fountain-pen fillers. Fountain-pen fillers may actually be employed, but in the Tropics their usually thin-walled rubber nipples are soon apt to become perished, and it is therefore better to use pipettes which are easily made in the following way from $\frac{1}{4}''$ internal diameter glass tubing. Under the flame of a paraffin blow-lamp draw a piece of $\frac{1}{4}''$ internal diameter glass-tubing into pipette form with a stem about $3''$ in length. From glass tubing of the same diameter, cut off a piece about $\frac{1}{2}''$ in length, and seal both ends by revolving them in the flame. Cut off $2\frac{1}{2}''$ of thick-walled rubber tubing of a diameter large enough to slide over and fit the stem of the pipette tightly. Wet the inner walls of the rubber

tubing and slip it over the uncontracted end of the pipette so that it envelopes the stem to the extent of 1″. Then wet the small piece of glass tubing whose ends have been sealed, and, with this, plug the open end of the rubber tube, pushing the glass-plug well into the tube. About an inch of the bore of the rubber tube is left containing an air-space which can be compressed between the finger and thumb *(Fig. 56, below)*. Incidentally, it should

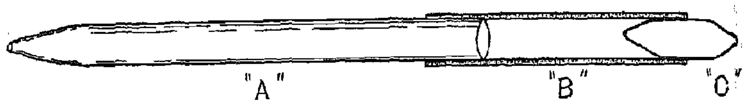


FIG. 56.—TO SHOW CONSTRUCTION OF SPECIAL PIPETTES
"A," glass stem; "B" thick-walled rubber-tubing; "C" glass stopper

be added that the hole in the point of the pipette should have a diameter of about $\frac{1}{8}$″ to allow even the large larvæ and pupæ to be sucked in. These pipettes will be found to be particularly well suited to the work, as the thick-walled rubber tubing expands almost instantly on the release of pressure upon it, and so by rapid suction captures the larvæ or pupæ before they have time to escape.

Collecting Adult Mosquitoes from their Natural Resting-places. The easiest method of capturing adult mosquitoes from their natural resting-places without causing damage to their scale ornamentation is perhaps by the use of glass tubes. Ordinary test-tubes are satisfactory, and it will be found that if the open end of the tube is slowly brought up below the resting insect, it will usually fall into the tube; the reason for this being that mosquitoes which are in a "hanging" position, in commencing flight, drop from the surface instead of springing from it. If the open end of the tube is within half-an-inch of the body of the insect before it is disturbed, the drop it makes preparatory to flight usually ensures its capture.

Resting mosquitoes show a preference for dark secluded situations at all times. In houses they will frequently be found in dark corners on the ceilings or walls, on the under sides of tables and chairs, in cupboards, in the folds of curtains or other hangings, in cellars, and under the raised foundations of houses, etc. A large number of species frequent stables, pig-sties and poultry-houses, and in these situations may be found in the secluded corners. Nevertheless, it is well to note that certain species which enter houses to bite the inhabitants, rarely remain in the house after they have fed, and always attempt to get out of doors immediately after. Consequently, the presence of these species is not detected by a later search during the daytime. In order, therefore, to determine what species are about, it is advisable to make additional collections while the insects are active. Moreover, it should be noted that the species which never, or only occasionally, attack man, have their resting-places in the open ; in tree-holes, in the shelter of fallen trees, in holes in the ground, in caves, in thickets, and even at times in the shelter of long grass. To capture the adults of these species, a sweeping-net should be employed. Often the adults of rare species may be captured at the sites of their breeding-places as they emerge from their puparia, and male adults are sometimes to be found in these situations when they can be discovered nowhere else.

Keeping Mosquitoes in Captivity. Insect Cages. Of these there are a host of designs. A useful pattern for permanent laboratory use is shown on the bench in *Fig.* 53, *facing page* 225. In this the main structure and floor are of wood, one of the vertical sides being also of wood, in which there is an arm-hole protected with a sleeve of mosquito-netting. Below the arm-hole is a wide trap-door

for the insertion into the cage of water dishes, etc. One of the other three vertical sides is glazed in, and the remaining two sides and the top of the cage are closed in with mosquito-netting. If the cage is suitably arranged, the glazed side prevents a direct draught through the cage, and enables the insects within to be seen distinctly. A pattern of semi-out-of-doors cage is shown in *Fig.* 52, *facing page* 225. In the construction of these cages the sash of one of the laboratory windows is removed, and a wooden panel, containing a wide trap-door, an arm-hole and a small glass window, is fitted in the original window space. On the outside of the window a wooden framework is erected, including a wooden or cement floor, and a wooden roof protected by lead-sheet or other waterproof covering. The three sides are closed in with copper or phosphor-bronze mosquito netting, and the whole cage may be protected from violent winds by a thick canvas covering or by single canvas side-pieces when it is desired to keep off the draught from one direction. Perhaps the simplest, but none the less efficient and useful, mosquito cages may be made as follows. From galvanised fencing wire, form 3 hoops, 12″ in diameter. Solder the ends of each hoop together, and, to the inner circumference of the hoops, four 18″ lengths of similar wire are soldered in such a way that the three hoops are arranged one above the other with the four supporting wires symmetrically arranged within the hoops, so as to have one hoop at the lower end, one at the middle and one at the top end of the wires. These wire skeletons are then enclosed in tubular cases of mosquito-netting, which are made by sewing the two 36″ edges of a piece of mosquito-netting measuring 36″ by 40″ up one side of the wire frame. If the frame is correctly placed within the tubular covering, 9″ of the covering will project at each end. Both ends of the netting should then be

fitted with draw-cords by which they may be closed *(Fig. 57, below)*. These cages will be found to act admirably if, when the insects are contained, they are kept out of a direct draught. By leaving one end of the netting open and standing the cage vertically over dishes containing larvæ and pupæ, these cages may be used to hold captive the adult insects which emerge.

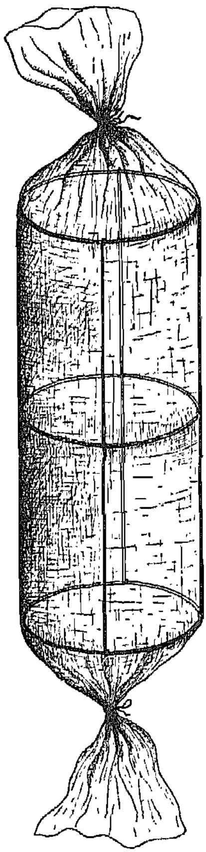


FIG. 57
WIRE-FRAME MOSQUITO CAGE

A Method of keeping Malaria-infected and other fed Mosquitoes in a Favourable Environment. In the Tropics particularly, mosquitoes which are used in malaria transmission experiments are apt to die when they are necessarily imprisoned in small glass tubes, owing to the dry state of the atmosphere within these tubes. To add a few drops of water to the tubes usually results in the death of the captive mosquitoes, either by super-saturation of the contained air, or by the whole of the inner walls of the tubes becoming wet by condensation. The optimum conditions for the life of a fed mosquito are, that the insect shall rest comfortably, that there shall be a free play of air within the tube, and that while the air within the tube shall contain a high concentration of water vapour, it shall yet not contain sufficient to reach the dew-point of the surrounding atmosphere. These optimum conditions are attained by the following method (*Fig.* 58, *page* 238) :—

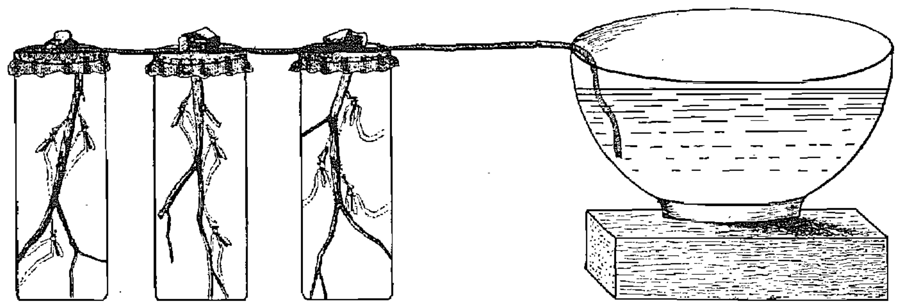


Fig. 58.—A Method of Keeping Malaria-Fed Mosquitoes in a Favourable Environment

The *unfed* mosquitoes should be placed in glass tubes measuring 4″ by 1¼″ in diameter—a common size of specimen tube. Before the insects are placed in the tube, a small dried twig should be inserted in such a way that the upper end of the twig does not reach quite to the top of the tube. Place the unfed insects—not more than three together—in these tubes and close the mouths of the tubes by small squares of mosquito-netting tied over their open ends with cotton or light string. Do not use rubber bands to hold the mosquito-netting in place, as the rubber perishes rapidly and, by breaking, may unexpectedly release the insects. Allow the mosquitoes to feed by inverting the tubes over the patient's skin, and when they have fed, arrange the tubes in a line on a table. Across the tops stretch a length of ordinary lamp-wick, about ¾″ in width, so that the mouths of the tubes are not entirely covered by the wick. One free end of the wick is now to be placed in a bowl containing water which by capillarity will be drawn along the wick over the tubes and so keep the air within near the point of saturation. A small stone should be placed on the wick to hold it in position over each tube, and by raising or lowering the height of the bowl water-reservoir the flow of the water can be exactly controlled. If the tubes are spaced in line an inch apart, each length of wick will be found to serve up to a dozen satisfactorily. By this means I have found it possible to keep malaria-infected mosquitoes alive even in exceedingly hot dry atmospheres when it has been found impossible to do so in other ways. Half a raisin should be placed on one side of the wick on the uncovered portion of the mosquito-netting; the raisin is kept constantly moist and provides the insect with fruit sap, which I have found advantageous both to the life of the mosquito and apparently also to the development of the plasmodia.

Notes on Feeding Captive Mosquitoes. It is useless to attempt to feed a captive female mosquito soon after it has emerged from the puparium. Recently emerged specimens will never be found to desire blood-meals, and until the chitin of the mouth-parts has had time to harden for at least 12 to 24 hours after emergence, the mechanism of the proboscis is not able to undertake the work of skin puncture. Usually it will be found that female mosquitoes of those species who show no special predilection for a particular class of host are quite readily induced to feed if they are held captive in a tube inverted over the bare human skin, provided that care is used not to alarm the insect during the procedure. Insects to be fed should be placed in tubes some time beforehand, so as to allow them to become accustomed to the tubes, and, in offering them a blood-meal, the tubes should be carefully lifted and inverted over the skin, avoiding all unnecessary disturbance. Frequently it will be found that a mosquito seems to be delighted with the proximity of a source of food and immediately begins to explore the skin with its proboscis. Generally it finds no difficulty in locating a suitable site for the insertion of that organ, and within a minute or two will have a fully-distended abdomen and be replete with blood. On the other hand, it will not infrequently be found that mosquitoes which at first attack the skin with enthusiasm, and either get, or fail to get, their proboscides properly inserted, after a single or several separate unsatisfactory attempts to obtain blood, lose all enthusiasm for the search and cannot thereafter be induced to make other efforts. The explanation of this phenomenon would appear to be either that the insect has in some way a malformation of the proboscis, or, in the case of insects which exhibit this proclivity with one host and not with another, that the skin of the host in the first instance is

either too full of elastic and connective tissues for the blood to be tapped by the proboscis, or that it is in some manner distasteful to the insect. Nevertheless, investigation has shown that some slight defect in the proboscis sufficient to debar the sufferer from ever attaining a blood-meal is a fairly common defect among female mosquitoes.

In feeding on animals, mosquitoes are always on the brink of disaster, but disaster of a peculiar form sometimes overtakes them from the fact that the proboscis is at times apt to become so firmly embedded in the tissues of the host that it cannot be withdrawn by the insect. This is particularly likely to happen if the host makes some movement which stretches the skin on which the feeding mosquito is situated. The proboscis may then become partially bent, or elastic fibres in the tissues of the host compress and grip the proboscis. A luckless mosquito attached to the host in this manner makes every attempt to release itself without avail.

Food starvation in mosquitoes evidences itself by the abdomen becoming more and more transparent to light. Water starvation, in addition to food starvation, causes the abdomen to assume a bent condition so that the tip of the abdomen bends downwards and forwards, giving this part of the body a ventrally arched appearance. Mosquitoes can tolerate a considerable degree of food starvation, but rapidly die if starved of water.

Starved mosquitoes which have not reached a state of starvation sufficient to reduce their activities, are prone to exhibit a remarkable phenomenon, *i.e.*, sudden death. Very often I have noticed that when starved mosquitoes which,

nevertheless, are active enough to be considered normal, are presented with the opportunity of attaining a blood-meal, they at once avail themselves of the offer only to die suddenly on the skin of the host either before they have had time to pierce the skin, or immediately after they have done so. The phenomenon has every appearance of death being due to excitement shock.

It has been often stated that mosquitoes seem to prefer the blood of persons who are newcomers to the Tropics. Mosquitoes undoubtedly show a preference for the blood of some people over that of others, but the idea that newcomers are always preferred is incorrect. The reaction to mosquito bites in persons who have not previously been so subject to attack is often more violent than is the case with old residents, and consequently the mosquito nuisance is more noticed by newcomers. I have often observed that many an old resident is frequently preferred to the newcomer. Personally, although I reside often for long periods outside the tropical zone, I am disliked by mosquitoes, and during our campaign in Mauritius there was clear evidence that the newcomers (a member of the Rockefeller Hookworm Commission, an English member of the Medical and Health Department, and myself) found ourselves much less subject to attack than were many of the old residents of that Island.

Field Technique.—Collecting Larvæ and Pupæ.— One of the important items in the equipment of the field worker is the "dipper," which takes the form of a long-handled hemispherical ladle, preferably white-glazed inside. It is useful to have a series of several sizes.

There is a right and wrong way of using even such a simple thing as a "dipper." I have

frequently seen untrained persons searching for larvæ in a pond and failing to find them, largely on account of faulty methods—in dipping too slowly and too deeply, and in dipping in the situations that were just the most unlikely to be frequented by the particular species that were sought. The dipper should always be thrust through the surface of the water swiftly, in such a way that the side and not the bottom of the ladle first enters the water. The handle must then be turned at once to lift out the ladle from the immediate vicinity of the "dip," instead of dragging it along through the water. Obviously, if the larvæ or pupæ are scarce, in dragging the dipper along we are almost certain to wash out any specimen we may at first have had the good fortune to capture. Moreover, do not stand at the edge of the water talking, or perhaps waving your arms about, before making a dip. If so, at least 90% of the larvæ originally at the surface will have fled to the bottom of the pool, and perhaps remain there until you have gone away again, recording "no larvæ or pupæ found." Instead, approach the edge of the breeding-place cautiously, remain stationary, if possible, for a minute or two, and then rapidly thrust the dipper into the water in the manner described. With many species, or when the larvæ and pupæ are numerous, such precautions are no doubt a little unnecessary, but it is as well to remember that some species are extremely timid, and are not very likely to be captured without these "stalking" tactics. The larvæ and pupæ of *A. funestus*, for example, may be missed repeatedly if care is not taken to avoid frightening them from the surface.

In regard to the position at which to dip; along the edges of the breeding-place is always the most likely place at which to get the majority of larvæ.

Often it is better, if the edges of the breeding-place are weed-clad, to drive the dipper at an angle of 45° hard in against the just submerged roots of the plants. In waters with a large open expanse in the middle it may be safely assumed, if there are no larvæ at the edges, that there are none either at the middle, and in any event there are not likely to be larvæ in ponds far from weed-cover. Fish are the chief natural enemies of mosquito larvæ, and for this reason larvæ are rarely found in open large expanses of water. On the other hand, if the water contains floating vegetation, as many larvæ, or more, may be at the middle of the pond as there are at the banks.

Certain species show marked preference for direct sunlight, other species show an equal preference for shade, still others like, or tolerate, either sunlight or shade. Therefore, if the particular tastes of the larvæ in this respect are not known, and none are found in shady situations, search in the sunlit areas of the same breeding-place. In the case of anophelines and certain short-siphoned species, on a windy day more larvæ are usually to be found along the edges of the pond which face the direction of the wind, having been blown there by the air currents across the surface of the water.

In water flooded by direct sunlight, and where there are submerged water-plants, the larvæ of some species leave the surface, descend and attach themselves by their siphons to the bubbles of oxygen transpired by the plants. Consequently, to discover these larvæ in such situations, it is necessary to get down on one's hands and knees and peer into the water in an attempt to see the larvæ. If a suitable angle of vision is chosen, it is generally possible, in clear water, to see for a considerable depth, and if the presence of the larvæ is detected,

and they cannot be reached with the dipper, the weeds should be stirred violently with a long stick to release the adherent bubbles of gas, and, after waiting a few minutes, the larvæ will generally be found to rise to the surface.

Species of the Genus *Tæniorhynchus* are permanently attached to the stems of submerged plants by their siphons, which are specially adapted to pierce and hold the plant tissues, the oxygen necessary for respiration purposes being obtained directly from the air-vessels of the plant. The breeding-places of the species of this genus are almost invariably rural sunlit ponds or small lakes, and if specimens are required they must be sought for by detaching a quantity of the weeds for close examination in the laboratory. One species of *Tæniorhynchus* was found during my survey in Mauritius during 1922-1923, and it would be interesting to find the larvæ of this, at present, unidentified species.

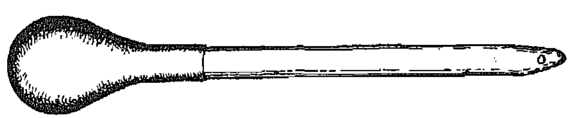


Fig. 59

Pipette for Collecting Tree-Hole Larvæ and Pupæ

The Tree-hole Breeding Species. In collecting the tree-hole breeding species the work, in some ways, is easier. Part of the water is simply removed from the hole—in the case of large holes, by a small dipper, or, if the hole is small, by means of the tree-hole pipette *(vide infra, Fig. 59, above)*. The main labour of this type of collecting is in discovering the tree-holes, which may be found to occur in the tree trunk or in the larger branches at some distance from the ground. If no larvæ

are present in the water, it is always as well, nevertheless, to collect a sample and allow it to remain in the laboratory undisturbed for some days in case eggs are present that will later hatch.

The Tree-hole Pipettes. In searching tree-holes, this type of pipette is indispensable. They may be easily made as follows: Obtain a piece of glass-tubing about $\frac{1}{2}''$ in internal diameter and $12''$ in length. Near one end draw off a short stout-walled constriction. This can be done by evenly heating only a small area of the glass tube in the flame of a paraffin blow-lamp and pulling the ends apart *slowly* when the glass is quite soft. Cut the glass across the constriction and discard the smaller portion. Heat the tip of the contracted end of the pipette until the opening is closed by the fusion of the glass and continue heating the tip until a small "button" of glass is formed. (This "button" and solid glass end will largely protect the end of the pipette from damage should it strike a hard substance when being inserted into a tree-hole.) Allow the glass to cool, and then, on one side only, heat a small area of the glass wall about $\frac{1}{2}''$ from the solid tip. When the glass softens, keep it steadily in the flame, and with considerable force blow down the open end of the tube so as to explode the glass in the softened area. By playing the flame all over the hole, any projecting glass can be made to contract to a uniform level, and the edges of the hole will be thickened. A hole from $\frac{1}{8}''$ to $3/16''$ in diameter is required. To the other end of the pipette a large thick-walled rubber bulb is fitted—such as are used for aural syringes. If an aural syringe-bulb is unobtainable, the bulb of a motor-horn makes a good substitute when the open end of the bulb is made to fit the diameter of the tube by a suitable plug.

Anti-Malaria and Anti-Mosquito Surveys. The difference between an anti-malaria and an anti-mosquito survey is simply that in the former the investigations are strictly limited to the bionomics and breeding-places of the anopheline mosquitoes, to determining which of the species are the local vectors of the disease, what species are naturally infected, and which can be infected experimentally; the extent of the infection among the population, the species of malaria plasmodia concerned, and the proportion of each species responsible for the epidemic. Anti-mosquito surveys, on the other hand, deal with the bionomics and breeding-places of all the local species (culicines and anophelines alike, irrespective of their tribal divisions), including attention to which represent species dangerous to public health.

Whichever type of campaign the reader finds himself called upon to undertake, there are a few suggestions which he may find helpful.

In the first place, the composition of the necessary staff is of considerable importance. For either type of survey the director must necessarily be a fully-trained entomologist with a thorough knowledge of the Culicidæ. In anti-malaria surveys the director, in addition to this essential entomological qualification, must either himself have a medical training or have medical men with a special knowledge of malaria as members of his staff. Naturally, the other members of the survey personnel will largely depend on the extent of the territory to be surveyed and upon the financial resources available, but an indispensable member for a survey and campaign of any magnitude is a civil engineer, possessing special qualifications in drainage operations. His services will be found of the greatest value in dealing rapidly and effectually with the abolition of the larger breeding-

places. The importance of the work of the engineer in anti-mosquito campaigns is very well illustrated by Le Prince & Orenstein's "Mosquito Control in Panama," and in a recently published book, "The Engineer and the Prevention of Malaria," by Henry Home, published by Chapman & Hall, Ltd., London. If funds will permit, the staff should include one or more assistant entomologists and a skilled laboratory assistant.

The semi-scientific field staff will consist of a gang of trained "mosquito searchers," who often may very well be an intelligent group of natives who have been trained in the recognition of mosquito adults, pupæ, larvæ and eggs by one of the entomologists, to whom they should be directly responsible.

There is necessarily also a "maintenance gang," composed again of intelligent natives under native foremen, who are employed in the maintenance in operation and repair of the completed anti-mosquito measures. This gang should obviously be responsible to the civil engineer.

Finally, there is the labour gang, composed of as many men as are required, or as many as funds will permit.

It should be emphasised at the start that once proper plans for the campaign have been laid, rapidly and soundly executed operations, even if entailing large initial expenditure, are the most economical in the end. It is often unconsciously easier to spend a much larger sum in instalments, and to get less for it, than to spend half the sum rapidly on well-laid plans in a successful achievement of our aim.

When the funds and the scientific and semi-scientific staff have been obtained, and the central field laboratory has been established, a certain

time is advantageously spent in a preliminary survey of the work to be undertaken, before launching the main part of the campaign. Large maps of the territory and sectional maps of the districts should be erected in the laboratory, and the director, entomologists and engineer should form a clear understanding of the topography of the region by numerous excursions in the different districts. If the territory is large, it is far better to decide to operate primarily in one area, *and to complete the work therein,* before extending the activities, instead of attempting to do a little everywhere. Partially completed operations are often worse than useless, and are invariably uneconomical.

Once the director and his scientific staff are conversant with the topography and local conditions of the region, the work of the mosquito survey can be initiated, either over the whole region, if it is comparatively small, or, if large, in the selected area. The "mosquito searcher" gang may then receive a preliminary training in the recognition of mosquitoes at all stages of their life-history. In the case of Indian or African natives, I have found this knowledge is very rapidly acquired. One or two of the most intelligent individuals should be given the rank of headmen or foremen, and under them each member of the gang is sent out to collect mosquito larvæ and pupæ from all potential breeding-places. Needless to say, each man is provided with a "dipper" and collecting tubes, and they must receive strict injunctions to record faithfully the particular breeding-places where each of the respective batches of specimens was found. One of the entomologists will receive the collections and records at the end of each day, identifying the species and making further records by means of suitably marked pins placed on the maps to mark the sites of the recorded breeding-places. If

possible, each member of the mosquito gang should be informed of his finds, and be instructed in the specific characters of the different specimens. This stimulates and maintains interest, and it is remarkable how soon the natives learn these characters and, with enthusiasm, are able themselves to state the names of the species they have captured. Until experience has taught the director which of the members of the gang are to be thoroughly trusted in their statements, he and the other entomologists should check the records by visiting the different recorded breeding-places and collecting larvæ to see that the records are correct.

If, for the first six months of the campaign in territories where the mosquito fauna has not previously been carefully studied, the work is confined solely to forming records of the collection of the local species, their particular breeding-places and the specific bionomics, it will in the end be found that a great deal of invaluable information has been acquired which later will constantly indicate ways of concentrating the attack against what are found to be the dangerous species. Obviously, in any mosquito survey, the number of records of species and their breeding-places are greatest at the beginning ; practically every collection of water holds its quota of the mosquito population, but as time goes on the record of additional species is more and more infrequent, and the records very soon afterwards begin to give a fair indication of the specific bionomics.

Even in campaigns directed to anti-malaria efforts, while naturally perhaps the first and main object will be the study of the anopheline species, it is highly desirable, as time and opportunity permit, that the survey, in the interest of both scientific progress and public health, be extended to include the local culicine species also.

In anti-malaria campaigns, a matter of vital importance, after the investigations have shown what anopheline species are present, is to determine which are, and which are not, the species responsible for the transmission of the disease. In all regions where several species of anopheles are found, almost invariably some are, and some are not, the vectors of malaria. The essential importance of this determination is of course to enable a limitation of the necessary anti-measures to be imposed, so that all the efforts of the campaign may be directed against the proved vector-species instead of attacking the anophelines generally in any locality at a needlessly greater expense in time and money. Fortunately, the bionomics of practically all species of local anophelines have specific characters, which, in the majority of cases, afford means of limiting the necessary efforts to check the breeding of the particular species with which we have to contend.

In order to determine the important anopheline vectors, if the question has not been previously settled, it is essential to discover by experimental infection which species of the anopheles acquire infection. This can be easily accomplished by rearing the adults from their respective larvæ in the manner described on *page* 225, and feeding the adults on malaria-infected persons in whose blood the *gametocyte* stage of the malaria parasite is fairly numerous. To ensure fairly certain infection of those species of anopheles which are subject to malarial infection, only blood showing at least from 7 to 8 gametocytes per 100 fields of the microscope should be used to provide the mosquitoes with infective blood meals. Otherwise, if the gametocytes are less numerous the work of acquiring definite information as to whether certain species may become the intermediate hosts of the malaria plasmodia, is apt to become rather tiresome

and difficult, as a far larger number of separate experiments have necessarily to be undertaken. The adult female mosquitoes are then kept in captivity in the manner described on *page* 237, and from 4 to 8 days later they may be dissected (*pages* 213 *to* 220) to discover whether oöcysts are present on the stomach wall. The important vectors are usually infected readily, but the mere presence of oöcysts is not in itself sufficient to warrant the assumption that the species is to be regarded as actually dangerous, and consequently to be included everywhere in the anti-measures of the campaign. Apart from the experimental information which may have been obtained, the circumstantial evidence must be weighed carefully. If the species is rare, or is one which only breeds in small sites of a peculiar kind or in forest tree-holes, the likelihood of its being an important vector under natural conditions is extremely remote. For example, *Anopheles plumbeus* in England has often been shown experimentally to acquire malaria infection, but even if malaria were rife in England the bionomics of *Anopheles plumbeus* would make it most improbable that the species could at any time constitute a dangerous vector. The same thing is true, to a large extent, in the case of *Anopheles maculipalpis* in Mauritius. Experimentally it has been shown to acquire infection, but it is improbable that it plays any important part in the spread of malaria in the Island. Experimental evidence must always be regarded in the light of field observation and experience. Usually, however, it will be discovered at once that when a common, widely-distributed anopheline species is found to acquire experimental infection easily, that all the field observations also point to its being a dangerous vector. Nevertheless, mere numbers and the wide distribution of any particular species is not alone

sufficient to permit the assumption that it is consequently a vector. *Anopheles mauritianus* is an illustrative case, for the species is found in all parts of the Island; it will enter houses and attack man; but there is neither circumstantial nor experimental evidence to cause any suspicion that *Anopheles mauritianus* in Mauritius plays a part in the spread of malaria.

Numerous examples of a similar kind might be quoted from all parts of the world to demonstrate how important it is to gain sound scientific data about the local species before any attempt is made to launch a successful anti-malaria or anti-mosquito campaign involving economical financial expenditure. Not only is it possible to save large sums of money by directing the campaign solely against the actually dangerous species, but by the concentration of our efforts to narrower aims, success in our endeavours is far more likely to be achieved.

Anti-mosquito Measures. It is beyond the scope of this book to enter into a description of the various ways of dealing with the abolition of mosquito breeding-places. They are fully described in many of the existing text-books. The important measures may be placed under the three headings :

Drainage Operations, Control by Larvicides, and Control by Fish.

Of these three measures the complete abolition of the breeding-places, when practicable, is the only fundamentally sound way of combating the mosquito species which are included in our aim. Often this measure, either by drainage or other means, entails for the purpose a financial estimate of alarming proportions, but invariably, if the cost can be faced and the work is well executed, it will be found in the end that this measure is the most economical. An outright purchase is a cheaper way

of acquiring anything than by paying for it in instalments, and, in most anti-mosquito campaigns, the latter method has usually the added penalty that there is no fixed date for the termination of the contract. For this reason the abolition of the breeding-places, once and for all, has the greatest advantage over the second means, namely, the use of larvicides.

Larvicides. The great drawback with larvicides is that, while they frequently perform their function admirably, their action is merely temporary and their application (often at considerable expense) has to be repeated at regular intervals, ad infinitum. Hence, for any beneficial result the work has to be continued indefinitely without the slightest hope of a possible respite and with the certain knowledge that the enemy will gain the upper hand again the moment the application of larvicide ceases. It may be safely said that more money has trickled or been thrown into mosquito breeding-places by the use of larvicides, without any permanent benefit, than has been spent on major drainage operations, which in certain localities have bought victory over mosquito-breeding for all time. Unquestionably, therefore, in any serious anti-mosquito campaign the use of larvicides as a general means of control is not to be considered. Larvicides, nevertheless, as a temporary measure while plans for permanently abolishing the breeding-places are being devised, or for rapidly getting rid of mosquitoes temporarily in any restricted area, must be admitted to have their uses. Two most important mosquito larvicides are: (1) paraffin, plus castor oil mixture, and (2) Paris Green, plus road-dust mixture. The paraffin plus castor oil larvicide is composed of paraffin (kerosene) 98·8 parts, castor oil 1·2 parts, and the quantity necessary for use in any given area varies considerably with the quality and specific

gravity of the constituent oil, but generally about 1 ounce of the oil-mixture to 15 square feet of water-surface will be found sufficient. Only enough to produce a thin continuous oil-film over the surface of the water is necessary. The Paris Green (copper aceto-arsenite) larvicide is composed of Paris Green 1 part, road-dust 100 parts, and is used in the proportion of 12 grams (0·43 ounces to 90 square metres—1000 square feet) of water-surface in the breeding-place. The mixture is thrown by hand in the direction of the wind across the face of the water in such a way that the powder is carried to all parts of the pond or marsh.

When using paraffin castor oil mixture, it is essential for the formation of a continuous oil-film over the surface of the water, that all weeds at the edges and within the breeding-place be removed before the application of the oil mixture. Otherwise the oil-film will not be complete, the forces of surface-tension checking the spread of the oil in the immediate vicinity of the weeds, and so enabling the larvæ to find safe shelter where such weeds occur. Usually, if properly applied, oiling will render a natural breeding-place "safe" for a period of two to three weeks—even considerably longer in some instances—but if the breeding-place is in an exposed position where high winds disturb the surface, the oil-film often rapidly disappears, partly by evaporation and partly by the oil being driven by the wind to the edges of the pond or marsh, where, by wave-action, it is absorbed by the surrounding soil.

The use of Paris Green instead of oil mixtures has consequently much to recommend it. In using Paris Green it is unnecessary to remove the weeds, as the dust falls between the stems and leaves, so reaching even the larvæ which may be ensconced under their shelter. The floating particles of this larvicide do not check the natural

excursions of the larvæ as an incomplete oil-film does, and therefore there is every chance of the larvæ sooner or later ingesting the poison.

Remember, however, that Paris Green is only an effective poison to the surface-feeders—the anophelines—and it has little or no effect upon the culicines, which feed below the surface. Paris Green will float on the surface of still water for several hours, but once the particles are "wetted" they sink to the bottom of the breeding-place and are no longer useful as a larvicide. For this reason it is clearly necessary, when using Paris Green against anopheline larvæ, never to attempt to use it when the surface of the water is rippled by wind. It has its most potent action on warm, still days, when the larvæ are feeding actively and when there is just sufficient wind to carry the dust cloud gently over all parts of the breeding-place.

Control by Fish. As I pointed out many years ago, fish have a strictly limited application in anti-mosquito measures. Under natural conditions they have been found to have no appreciable influence in checking mosquito-breeding. Under artificial conditions, where the water surface may be kept free from weeds, the use of fish will at times be found of great value. Fish may be advantageously utilised by introducing the small larvivorous species into all artificial waters, such as unscreened water tanks, ornamental ponds and drainage canals, *provided* that all weeds and other forms of vegetation are not allowed to grow in these situations.

The great danger in the use of fish for controlling the breeding of mosquitoes is the false sense of security their presence is apt to engender in the mind of the user, unless the conditions for their proper activities are carefully and constantly maintained.

Conclusion

Within the limitations of available space an attempt has been made in this little book to put into the hands of field workers in the Tropics the essential information needed to help them in the scientific prosecution of their labours. I trust, moreover, that it will be found to guide the worker from the elementary, and often insufficient, information to be obtained in most of the simpler text-books on mosquitoes to a fuller appreciation and use of the information contained in the more advanced works, for undoubtedly most field workers are too often at present debarred from achieving more, simply by lacking a guide which will lead them further.

The number of men engaged in anti-malaria and anti-mosquito measures is now to be reckoned in thousands, and if but a tenth part of their endeavours were conducted with a clearer conception of the underlying principles of entomological method, our yearly advance upon these insect enemies would be vastly increased.

There are few ways in which large sums of money can be more vainly wasted than in ill-conceived and unscientifically-organised anti-malaria and anti-mosquito campaigns, but—and it is a "but" with true significance—with trained workers the expenditure of money has no greater or more lasting reward than by what it can achieve when carefully spent on measures that are certain of success. This certainty of success has been demonstrated in many parts of the world; all that is now wanted for general success is a wide dissipation of our already acquired knowledge and the consequent further additions which will speedily

accrue. In this connection I shall shortly be publishing a Catalogue of the known Genera and species of mosquitoes and their recorded distribution throughout the world.

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